

30 B

Reproduction and Development

The 100 trillion cells of your body are truly awe-inspiring, when you think that they all started from a single, fertilized egg. They stand as proof of the ability of human cells to grow and reproduce.

Every year, approximately 350,000 babies are born in Canada. With one of the lowest child mortality rates in the world, this woman will likely have a healthy son or daughter. Improvements in diet and a better understanding of environmental risk factors, such as alcohol consumption and second-hand smoke, have reduced the rate of health problems in babies. Healthy women are more likely to have healthy babies. Moderate exercise during pregnancy helps maintain the health of the mother and baby. Exercise promotes muscle tone, strength, and endurance—three qualities that can help the mother adjust to the weight increase during pregnancy, prepare for the physical challenge of labor, and make it easier to get back into shape after the baby is born.

Should problems arise, improvements in diagnostic techniques and emerging procedures, such as the treatment of an embryo in the uterus, have helped to improve the health of mother and baby.

As you progress through the unit, think about these focusing questions:

- How do reproductive systems function to ensure survival of the species?
- What mechanisms are responsible for regulating reproductive systems?
- What are the major processes and events of human embryonic and fetal development?
- How have reproductive technologies affected the functioning of reproductive systems?

UNIT 30 B PERFORMANCE TASK

Society and Reproductive Technology

The speed at which new reproductive technologies emerge can exceed our ability as a society to agree on their possible implications. Reproductive technologies are changing old definitions of motherhood and of parent. In the Performance Task for this unit, you will examine new reproductive technologies and assess their social and ethical implications.

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GENERAL OUTCOMES

In this unit, you will

- explain how survival of the human species is ensured through reproduction
- explain how human reproduction is regulated by chemical control systems
- explain how cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine, and environmental factors

Unit 30 B

Reproduction and Development

ARE YOU READY?

These questions will help you find out what you already know, and what you need to review, before you continue with this unit.

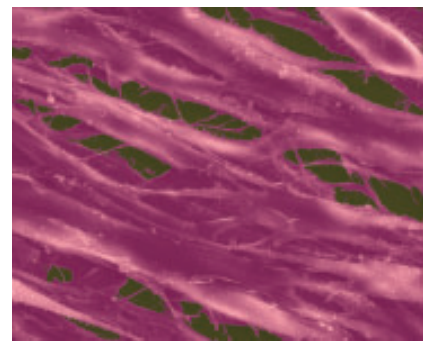
Knowledge

- Adult humans have developed from a single fertilized egg into a complex organism composed of many types of cells.
 - How does one cell grow into a multicellular organism?
 - If all the cells in your body came from the same fertilized egg cell, why don't they all look alike?
 - Why are there more of some cell types than others?

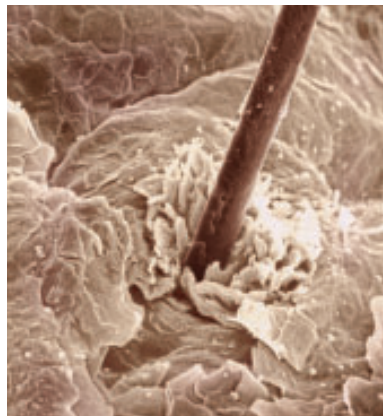
(a)



(b)



(c)



(d)

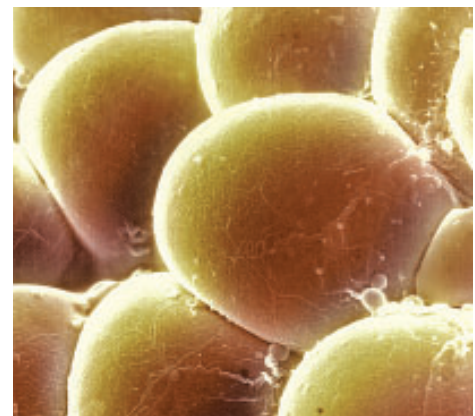


Figure 1

Photomicrographs of (a) a fertilized egg cell, (b) muscle cells, (c) epithelial cells, and (d) fat cells

- A quaking aspen located near Salt Lake City, Utah, may be the world's largest organism, according to Dr. Stewart Rood at the University of Lethbridge. What appears to be a grove of individual aspen trees is actually one organism with a common root system. The single organism covers 43 hectares! The tree-like shoots develop from runners (horizontal roots) that grow above or below the ground.
 - What are the advantages of reproducing by runners?
 - Do all the trees have the same genetic information since they are one organism? Explain why or why not.
 - List three other plant species that reproduce through runners.


Prerequisites

Concepts

- cell division
- cell specialization in multicellular organisms
- asexual and sexual reproduction
- chromosomes, genes, and DNA
- inheritance

Skills

- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
- use electronic research tools to collect information on a given topic

You can review prerequisite concepts and skills on the Nelson Web site and in the Appendices. 

A Unit Pre-Test is also available online.

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3. Over 2000 years ago, the Greek philosopher Aristotle proposed that heredity could be traced to the power of the male's semen. What observation or previous learning would allow you to support or refute this statement?
4. The time that unborn young spend developing in the uterus is called the gestation period. In mammals, the gestation period ranges from 16 days for golden hamsters to 650 days for elephants (**Figure 2**). Identify the advantages and disadvantages of short and longer gestation periods.



Figure 2

The gestation period in mammals ranges widely.

STS Connections

5. On April 25, 1978, the birth of a young girl, Louise Brown, caused people around the world to stop in amazement. She was the first baby ever conceived outside of the human body. A sperm cell fertilized an egg cell within a glass Petri dish in the laboratory (**Figure 3**). This revolutionary technique heralded the beginning of the new field of reproductive technology.
 - (a) Could a woman give birth to a baby who carries none of her genetic information? Explain your answer.
 - (b) Is it possible, through reproductive technology, for a 60-year-old woman to have a baby?
 - (c) What ethical problems might arise because of research in this field?

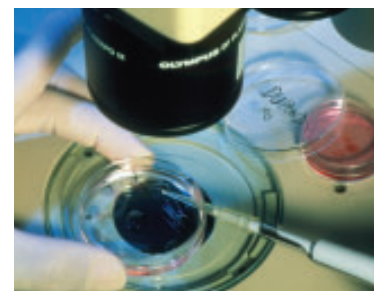

















Figure 3

In vitro fertilization

Reproduction and Development

► In this chapter

-  Exploration: Comparing Gametes
-  Mini Investigation: Microscopic Examination of the Testes
-  Lab Exercise 16.A: Understanding the Regulation of Male Sex Hormones
-  Web Activity: Structures of the Female Reproductive System
-  Mini Investigation: Microscopic Examination of the Ovary
-  Web Activity: Tubal Ligation
-  Lab Exercise 16.B: Hormonal Levels during the Menstrual Cycle
-  Web Activity: The Visible Embryo
-  Investigation 16.1: Observing Embryo Development
-  Web Activity: Dr. Keith Bagnall
-  Explore an Issue: Fetal Alcohol Spectrum Disorder
-  Web Activity: Fetal Rights and FASD
-  Web Activity: Creating a Database of Sexually Transmitted Infections
-  Case Study: Human Reproductive Technology
-  Web Activity: Reproductive Technologies

Reproduction ensures the survival of a species. Sexual reproduction contributes to the survival of a species because the offspring of a sexually reproducing species have different characteristics than their parents or their siblings. Natural selection acts on this diversity since individuals with characteristics that make them well-adapted to their environment have a greater chance of survival and of producing offspring of their own.

The survival of a species is also affected by the number of offspring each individual can produce. This number varies greatly among sexually reproducing species. Female oysters produce an estimated 115 million eggs for each spawning. Each year, female frogs produce hundreds of thousands of eggs for fertilization (**Figure 1**). Human females, on the other hand, have 400 000 egg cells, of which only about 400 mature throughout the reproductive years—from about the age of 12 years to 50 years. According to one source, the greatest number of children born to one woman is 57. The limited capacity of human females to produce sex cells contrasts with that of males. From about age 13 to 80 or 90, the average human male can produce as many as one billion sex cells every day.



STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. What advantage is gained from producing millions of eggs?
2. What mechanism helps ensure survival of a species for animals that produce single young at a single birth?
3. During the summer months, it is rare to find a male aphid. Female aphids reproduce asexually and give birth to other female aphids. In the fall, some females become males and the aphids reproduce sexually.
 - (a) What advantage is gained from aphids reproducing in two different ways?
 - (b) What advantage is gained from reproducing asexually?
 - (c) What advantage is gained from reproducing sexually?
4. Millions of sperm cells are released to fertilize a single egg cell. Why are so many sperm cells produced, if only a single cell fertilizes the egg?



Career Connections:
Diagnostic Medical Sonographer; Midwife; Pediatrician

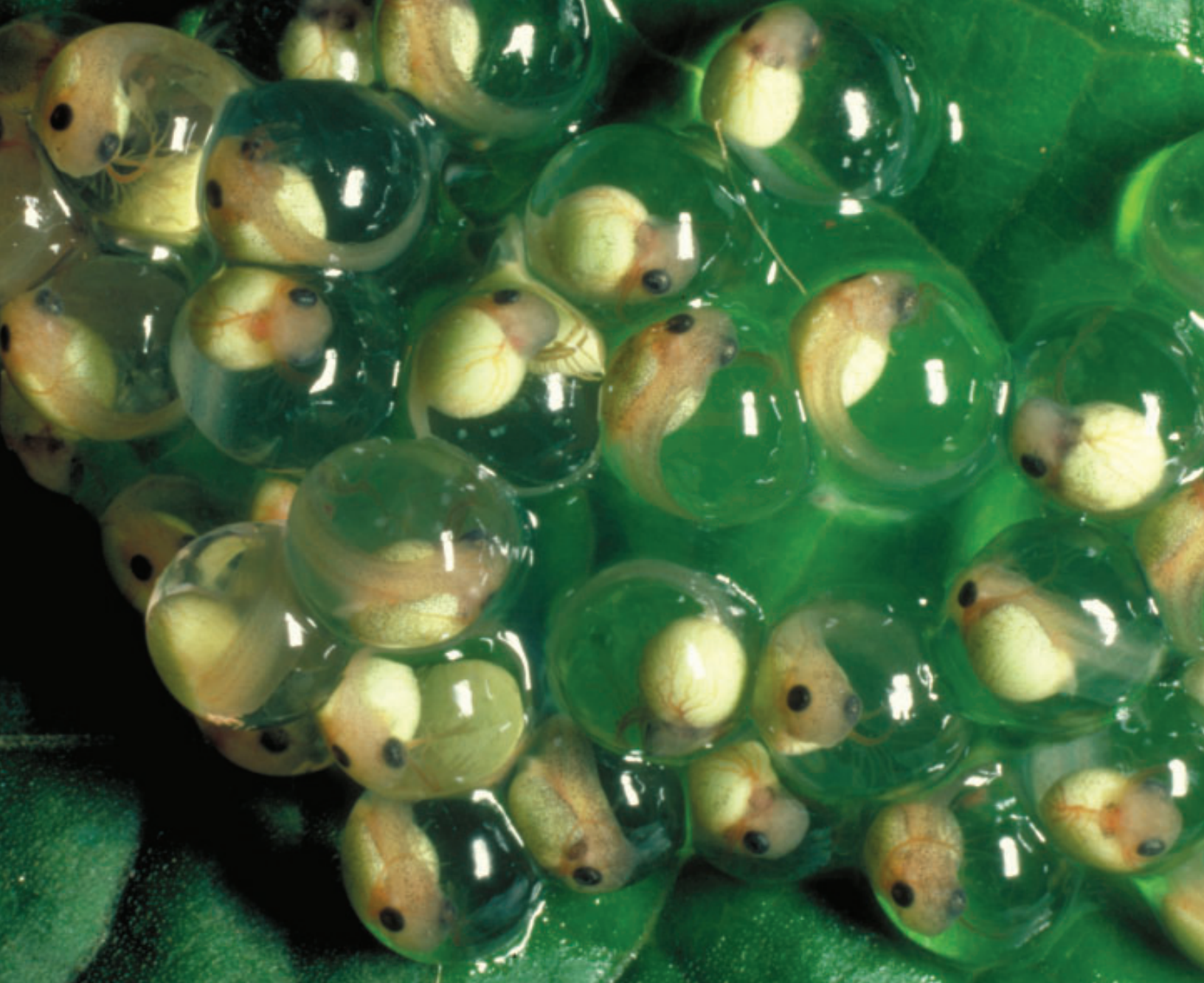


Figure 1

The production of many varied offspring ensures the survival of a species.

► **Exploration**

Comparing Gametes

Sperm cells and egg cells have different functions in reproduction. Sperm cells travel through the vagina into the uterus and then into the Fallopian tubes to fertilize an egg cell. Once fertilized, the egg cell undergoes multiple divisions, forming trillions of specialized cells of the human body. The structures of the egg and sperm cells provide clues to their function.

Materials: prepared slides of egg and sperm cells, light microscope

- Examine egg and sperm cells using a light microscope.
 - Compare the amount of cytoplasm found in the sperm and egg cell.
- (a) Estimate the size of the sperm and egg cell.
 - (b) What advantage is gained from the sperm cell having a dramatically reduced cytoplasm?
 - (c) What advantage is gained from the egg cell having a great amount of cytoplasm?

16.1 The Male Reproductive System

Recall that natural selection acts on the inherited traits of an organism, and that organisms with traits that are better adapted to their environment will be most likely to survive. (You can review this on pages 150–152 of this textbook.) Sexual reproduction gives rise to offspring that are different from their parents and from each other (with the exception of identical multiple births, such as twins). During sexual reproduction, specialized reproductive cells containing genetic material from two individuals (parents) join together. Since the two individuals both donate genetic material, the offspring will have a different set of inherited traits than either parent. The new set of traits may make the individual more or less adapted to the environment than its parent. When the environment changes, there is more variation for natural selection to act upon in sexually reproducing species. In contrast, during asexual reproduction, a single cell (parent cell) divides to give rise to two cells that have an identical set of inherited traits to each other and to the parent cell.

Humans reproduce by sexual reproduction. The specialized reproductive cells of humans are produced by, unite in, and develop within the organs of the male and female reproductive systems. The male gonads, the **testes** (singular *testis*), produce male sex cells called sperm. The female gonad, the **ovary**, produces eggs. The fusion of a male and female sex cell occurs within the female reproductive system, in a process called **fertilization**, which produces a **zygote**. The zygote divides many times to form an **embryo**, which in turn continues to grow into a **fetus**. In the rest of this section, you will find out about the biology of the male reproductive system.

testes the male gonads, or primary reproductive organs; male sex hormones and sperm are produced in the testes

ovary the female gonad, or reproductive organ; female sex hormones and egg cells are produced in the ovary

fertilization fusion of a male and a female sex cell

zygote the cell resulting from the union of a male and female sex cell

embryo the early stages of an animal's development

fetus the later stages of an unborn offspring's development

+ EXTENSION

Cancers of the Prostate

Prostate cancer is one of the most common cancers in males. In this extension activity, you will research how prostate cancer is detected and what treatments are available.

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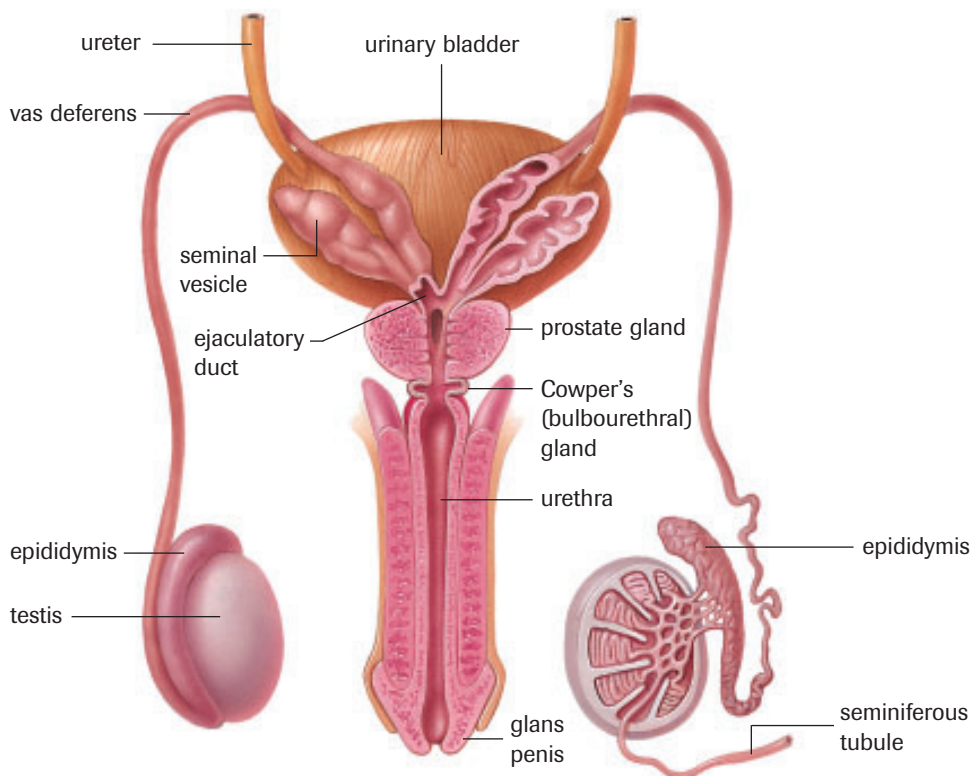


Figure 1

The male reproductive system. The urinary bladder and ureter are not part of the reproductive system.

Structures of the Male Reproductive System

Figure 1, on the previous page, illustrates the main structures of the male reproductive system in humans. Human male and female sex organs originate in the same area of the body—the abdominal cavity—and are almost indistinguishable until about the third month of embryonic development. At that time, the genes of the sex chromosomes cause differentiation. During the last two months of fetal development, the testes descend through a canal into the **scrotum**, a pouch of skin located below the pelvic region. A thin membrane forms over the canal, thereby preventing the testes from re-entering the abdominal cavity. Occasionally, an injury may cause the rupture of this membrane, producing an inguinal hernia. The hernia can be dangerous because a segment of the small intestine can be forced into the scrotum. The small intestine creates pressure on the testes, and blood flow to either the testes or small intestine may become restricted.

The temperature in the scrotum is a few degrees cooler than that of the abdominal cavity. The cooler temperatures are important, since sperm will not develop at body temperature. Should the testes fail to descend into the scrotum, the male will not be able to produce viable sperm. This makes the male sterile.

A tube called the **vas deferens** (plural *vasa deferentia*) carries sperm from the testis to the **ejaculatory duct**. Any blockage of the vas deferens will prevent the movement of sperm from the testes to the external environment. A surgical procedure, in which the vas deferens from each testicle is cut and tied, called a vasectomy, can be performed on males as a means of birth control (**Figure 2**). The ejaculatory duct propels the movement of sperm and fluids, called **semen**, into the urethra, which also serves as a channel for urine. A sphincter regulates the voiding of urine from the bladder. Both regulatory functions work independently and are never open at the same time. At any given time, the urethra conducts either urine or semen, but never both.

During sexual excitement, the erectile tissue within the penis fills with blood. Stimulation of the parasympathetic nerve causes the arteries leading to the penis to dilate, thereby increasing blood flow. As blood moves into the penis, the sinuses swell, compressing the veins that carry blood away from the penis. Any damage to the parasympathetic nerve can cause impotency, in which the penis fails to become erect. (Other causes, such as hormone imbalance and stress, have also been associated with impotency.)

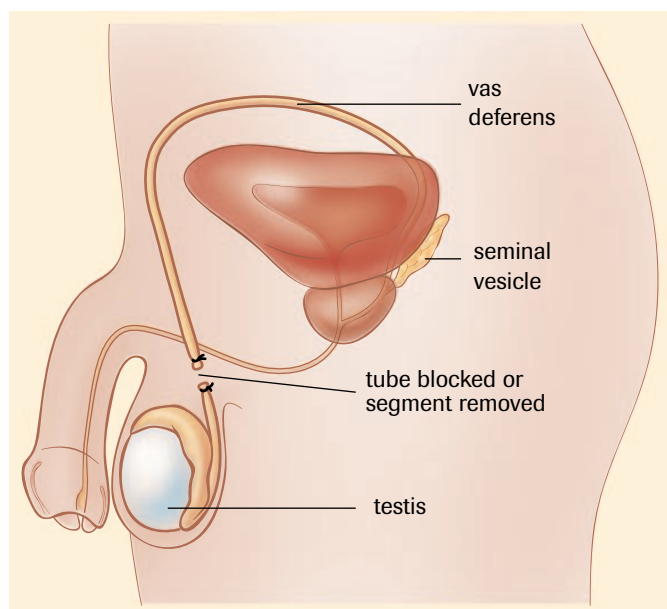


Figure 2

In a vasectomy, the vas deferens are cut, so that sperm can no longer exit the body.

+ EXTENSION



Male Reproductive System

View this animated side view of the male reproductive system and the roles of the various structures.

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scrotum the sac that contains the testes

vas deferens tube that conducts sperm toward the urethra

ejaculatory duct a tubule formed at the union of the vasa deferentia and the seminal vesicle ducts and opening into the urethra

semen (seminal fluid) a secretion of the male reproductive organs that is composed of sperm and fluids

DID YOU KNOW?

A Male Flower

The word *testis* comes from the Latin, meaning 'witness.' It has been suggested that the word *witness* comes from the idea that testes are witness to virility. The Greek word for testes is *orchis*. The orchid derives its name from the resemblance of its paired bulbous roots to the testes.

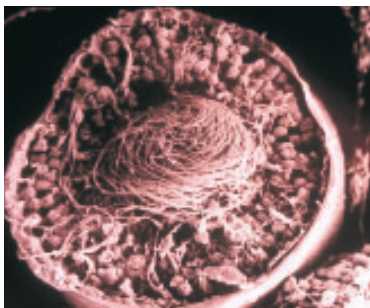


Figure 3

Scanning electron micrograph of a seminiferous tubule in cross-section

seminiferous tubules coiled ducts found within the testes, where immature sperm cells divide and differentiate

spermatogenesis process by which spermatogonia divide and differentiate into mature sperm cells

spermatogonia sperm-producing cells found in the seminiferous tubules

spermatocyte a cell that arises from division of spermatogonia during spermatogenesis

spermatid an immature sperm cell that arises from division of a spermatocyte

somatic cell any cell in a multicellular organism that is not a reproductive cell

Sertoli cell a cell that provides metabolic and mechanical support to developing sperm cells

epididymis structure located along the posterior border of the testis, consisting of coiled tubules that store sperm cells

Figure 4

Development of sperm cells inside the seminiferous tubule

Practice

1. What would happen if the testes failed to descend into the scrotum?
2. What is semen and where is it found in the male body? What function does it serve?

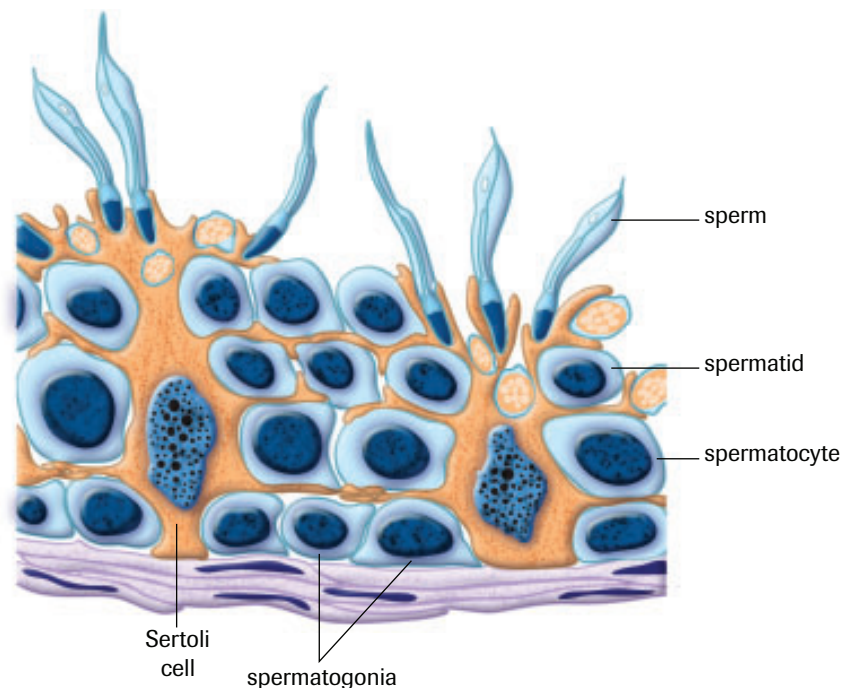
Spermatogenesis

The inside of each testis, which is only about 5 cm long, is filled with twisting tubes, called **seminiferous tubules**, that measure approximately 250 m in length (**Figure 3**). Seminiferous tubules are the site of **spermatogenesis**, which is the formation of sperm cells. The seminiferous tubules are lined with sperm-producing cells called **spermatogonia** (**Figure 4**).

During spermatogenesis, spermatogonia divide to form **spermocytes**. Spermocytes then differentiate into **spermatids**, which are immature sperm cells. The body cells (**somatic cells**) of humans usually contain 46 chromosomes. Spermatids have half this number (23 chromosomes) and, therefore, half as much genetic material as the spermatogonia. It takes 9 to 10 weeks for the spermatocytes to differentiate into sperm cells. You will learn more about spermatogenesis and its importance in Unit 30 C.

Specialized cells in the seminiferous tubules, called **Sertoli cells**, nourish the developing sperm cells until they are mature. Sertoli cells also provide a barrier between the blood and the seminiferous tubules (the blood-testis barrier). This barrier controls the entry and exit of hormones, nutrients, and other chemicals into the seminiferous tubules, which protects the developing sperm cells. If the barrier is damaged and sperm enter the bloodstream, the body can develop antibodies against its own sperm. This can result in a decreased ability to fertilize egg cells.

Although sperm cells are produced in the testes, they mature in the **epididymis**, a compact, coiled tube attached to the outer edge of the testis. Sperm cells in the epididymis begin swimming motions within four days. It is believed that some defective sperm cells are destroyed by the immune system during their time in the epididymis.



In many ways, the mature sperm cell is an example of mastery in engineering design. Built for motion, the sperm cell is streamlined with only a small amount of cytoplasm surrounding the nucleus (**Figure 5**). Although reduced cytoplasm is beneficial for a cell that must move, it also presents a problem. Limited cytoplasm means a limited energy reserve. In mature sperm, the energy-transforming organelles, the mitochondria, are found between the nucleus and the flagellum, the organelle that propels the sperm cell. An entry capsule, called the **acrosome**, caps the head of the sperm cell. Filled with special enzymes that dissolve the gelatinous outer coating surrounding the egg, the acrosome allows the sperm to penetrate the cell layer surrounding the egg.

acrosome the cap found on sperm cells, containing enzymes that permit the sperm cell to move through the outer layers that surround the egg

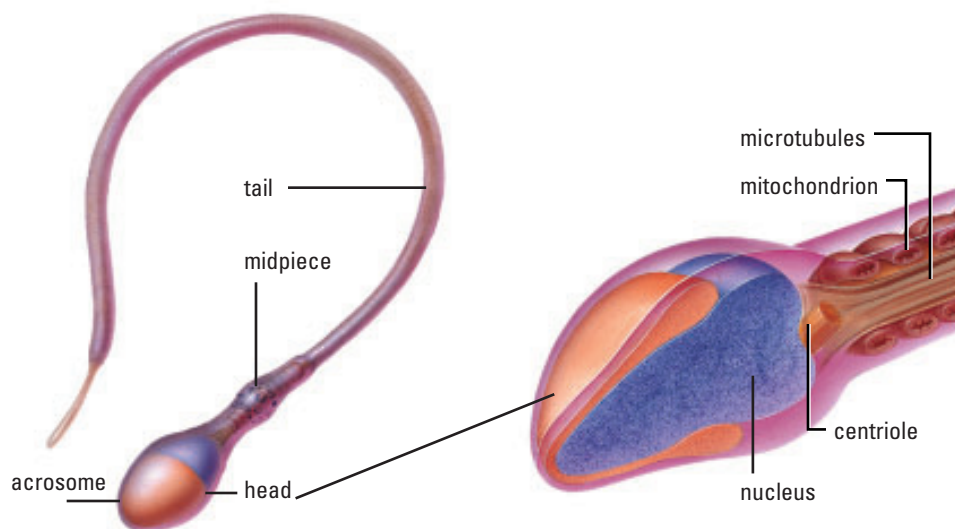


Figure 5
A human sperm cell

► Practice

3. What is spermatogenesis?
4. Explain how sperm are formed.

► mini Investigation

Microscopic Examination of the Testes

Purpose

To view structures within the testes

Materials: lens paper, light microscope, prepared slides of testes (cross-section), pencil

Visit the Nelson Web site to view micrographs of the testes to help you identify the structures on the prepared slides.

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- Using lens paper, clean the ocular and all the objective lenses of the microscope.
 - Rotate the revolving nosepiece so that the low-power objective is in place.
 - Position the prepared slide on the stage of the microscope and view the cross-section of the testes under low power.
 - Centre the slide on a single seminiferous tubule and rotate the revolving nosepiece to the medium-power objective. Use only the fine adjustment to focus the cells.
 - Locate an interstitial cell and a seminiferous tubule.
 - Rotate the nosepiece to the high-power objective lens. View the immature sperm cells within the seminiferous tubules.
- (a) Estimate the number of seminiferous tubules seen under low-power magnification.
 - (b) Estimate the diameter of the seminiferous tubule and size of the interstitial cell.
 - (c) Diagram five different cells within the seminiferous tubules.
 - (d) Would you expect to find mature sperm cells in the seminiferous tubule? Give your reasons.

seminal fluid the fluid part of semen, which is secreted by three glands

seminal vesicle structure that contributes to the seminal fluid (semen), a secretion that contains fructose and prostaglandins

prostate gland structure that contributes to the seminal fluid (semen), a secretion containing buffers that protect sperm cells from the acidic environment of the vagina

Cowper's (bulbourethral) gland structure that contributes a mucus-rich fluid to the seminal fluid (semen)

primary sexual characteristics physical characteristics of an organism that are directly involved in reproduction

Seminal Fluid

Sperm leave the body as part of a fluid, semen, which provides a swimming medium for the flagellated sperm. Ejaculation is the process by which the semen leaves a man's body via the penis. The vasa deferentia, seminal vesicles, ejaculatory duct, and prostate gland contract, forcing the semen to the base of the penis. Strong muscular contractions force the semen into the urethra and out of the penis. Every time a man ejaculates, between 3 and 4 mL of fluid, containing approximately 500 million sperm cells, are released.

The **seminal fluids** (the fluid part of semen) are secreted by three glands along the vasa deferentia and ejaculatory duct. Fluids from the **seminal vesicles** contain fructose and prostaglandins. The fructose provides a source of energy for the sperm cell. Recall that the sperm cell carries little energy reserves. Prostaglandins act as a chemical signal in the female system, triggering the rhythmic contraction of smooth muscle along the reproductive tract. It is believed that the contraction of muscles along the female reproductive pathways assists the movement of sperm cells toward the egg. The **prostate gland** secretes an alkaline buffer that protects sperm cells against the acidic environment of the vagina.

Cowper's (bulbourethral) glands (see **Figure 1** on page 512) secrete mucus-rich fluids prior to ejaculation. The fluids are thought to protect the sperm cells from the acids found in the urethra associated with the passage of urine. The fluid may also assist sperm movement.

Although sperm cells can exist for many weeks in the epididymis, life span is reduced when they come in contact with the various fluids in the semen. At body temperature, sperm cells will live only 24 to 72 hours. When stored at -100°C , sperm cells have been known to remain viable for many years.

► Practice

5. How does seminal fluid protect the sperm?

Hormonal Control of the Male Reproductive System

Table 1 summarizes the structures and functions of the male reproductive system. These structures are collectively referred to as the **primary sexual characteristics**. Primary sexual characteristics are directly involved in reproduction and are present at birth.

Table 1 The Male Reproductive System

Structure	Function
testes	<ul style="list-style-type: none">• produce sperm cells
seminiferous tubules	<ul style="list-style-type: none">• produce immature sperm cells
epididymis	<ul style="list-style-type: none">• matures and stores sperm cells in coiled tubules
vas deferens	<ul style="list-style-type: none">• carries sperm from the epididymis to its junction with the urethra
seminal vesicle	<ul style="list-style-type: none">• secretes fructose into the semen to provide energy for the sperm
prostate gland	<ul style="list-style-type: none">• secretes an alkaline buffer into the semen to protect the sperm from the acidic environment of the vagina
Cowper's gland	<ul style="list-style-type: none">• secretes mucus-rich fluids into the semen that may protect the sperm from acids in the urethra
urethra	<ul style="list-style-type: none">• carries semen during ejaculation• carries urine from the bladder to the exterior of the body
penis	<ul style="list-style-type: none">• deposits sperm into the female reproductive system during ejaculation• contains the urethra

The maturation and functioning of the male reproductive system is regulated by a number of hormones. As a male reaches puberty, the levels of these hormones change, which initiates the development of secondary sexual characteristics. **Secondary sexual characteristics** are external features, other than the reproductive organs, that differ between mature males and females. Male secondary sexual characteristics are summarized in **Table 2**.

Table 2 Secondary Sexual Characteristics of Males

<ul style="list-style-type: none"> • chest and abdominal hair • more facial hair than women • hair growth in armpits and pubis (crotch) • deeper voice due to enlargement of the larynx • larger, stronger muscles 	<ul style="list-style-type: none"> • fat deposits around the abdomen and waist • coarser skin texture • hands and feet usually larger than females • angle from thigh to ankle forms a straight line
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Perhaps the most important male hormone is testosterone. **Testosterone** is the primary male sex hormone. It is produced in the **interstitial cells**, which are found between the seminiferous tubules within the testes. Testosterone stimulates the maturation of the testes and penis and also spermatogenesis. It also promotes the development of facial and body hair; the growth of the larynx, which causes the lowering of the voice; and the strengthening of muscles. In addition, testosterone increases the secretion of body oils and has been linked to the development of acne in males as they reach puberty. Once males adjust to higher levels of testosterone, skin problems decline. The increased oil production can also create body odour. Testosterone levels are also associated with sex drive and more aggressive behaviour.

The hypothalamus and pituitary gland in the brain control the production of sperm and male sex hormones in the testes. The pituitary gland produces and stores the **gonadotropic hormones (gonadotropins)** that regulate the functions of the testes. There are two gonadotropins: follicle-stimulating hormone and luteinizing hormone. In males, **follicle-stimulating hormone (FSH)** stimulates the production of sperm cells in the seminiferous tubules and **luteinizing hormone (LH)** promotes the production of testosterone by the interstitial cells. **Table 3** provides a summary of the male reproductive hormones, their sites of production, and their functions.

Table 3 Male Reproductive Hormones

Hormone	Location	Description of Function
testosterone	interstitial cells	<ul style="list-style-type: none"> • stimulates spermatogenesis • promotes and regulates the development of secondary sexual characteristics • associated with sex drive levels
follicle-stimulating hormone (FSH)	pituitary gland	<ul style="list-style-type: none"> • stimulates the production of sperm cells in the seminiferous tubules
luteinizing hormone (LH)	pituitary gland	<ul style="list-style-type: none"> • promotes the production of testosterone by the interstitial cells
gonadotropin-releasing hormone (GnRH)	hypothalamus	<ul style="list-style-type: none"> • stimulates secretion of FSH and LH

secondary sexual characteristics

external features of an organism that are indicative of its gender (male or female), but are not the reproductive organs themselves

testosterone male sex hormone produced by the interstitial cells of the testes

interstitial cells cells found in the testes surrounding the seminiferous tubules that secrete testosterone

gonadotropic hormones (gonadotropins) hormones produced by the pituitary gland that regulate the functions of the testes in males and the ovaries in females

follicle-stimulating hormone (FSH) in males, hormone that increases sperm production

luteinizing hormone (LH) in males, hormone that regulates the production of testosterone

gonadotropin-releasing hormone (GnRH) chemical messenger from the hypothalamus that stimulates secretions of FSH and LH from the pituitary

inhibin a hormone produced by the Sertoli cells that inhibits production of FSH

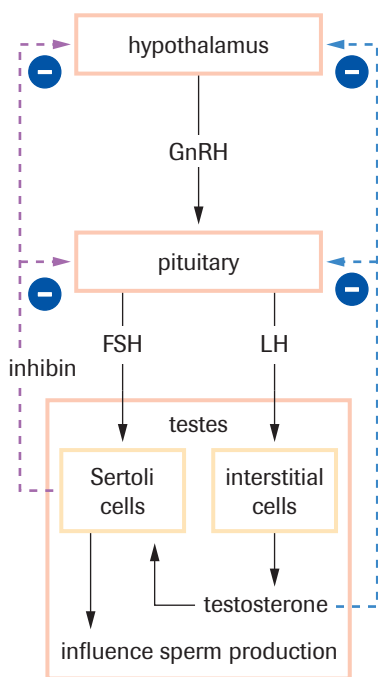


Figure 6
Negative feedback regulation of FSH, LH, and testosterone

Interconnecting negative feedback systems ensure that adequate numbers of sperm cells and constant levels of testosterone are maintained (**Figure 6**). Beginning at puberty, the hypothalamus secretes the **gonadotropin-releasing hormone (GnRH)** when testosterone levels are low. The secreted GnRH activates the pituitary gland to secrete and release FSH and LH. FSH acts directly on the sperm-producing cells of the seminiferous tubules, while LH stimulates testosterone production. Testosterone, in turn, stimulates spermatogenesis.

The broken lines on **Figure 6** show the negative feedback loops that maintain sperm counts and steady hormone levels. The feedback loop for sperm production is not well understood. When sperm counts are high, the Sertoli cells of the seminiferous tubules produce a hormone called **inhibin**. **Inhibin** sends a feedback message to the pituitary that inhibits further production of FSH. It also causes the hypothalamus to reduce its production of GnRH.

LH stimulates the interstitial cells to produce testosterone. A coordinated negative feedback system regulates LH and testosterone levels. High testosterone levels reduce LH production directly by feedback inhibition of LH release from the pituitary and indirectly by feedback inhibition of GnRH release from the hypothalamus. When high levels of testosterone are detected by the hypothalamus, it releases less GnRH, leading to decreased production of LH. Decreased GnRH output, in turn, slows the production and release of LH, which leads to lower testosterone production. Testosterone levels thus remain in check.

LAB EXERCISE 16.A

Understanding the Regulation of Male Sex Hormones

An experiment was performed in which the circulatory systems of two male mice (A and B) with compatible blood types were joined (**Figure 7**). The data analysis from the experiment is shown in **Table 4**. (Note that + indicates “found,” – indicates “not found.”)

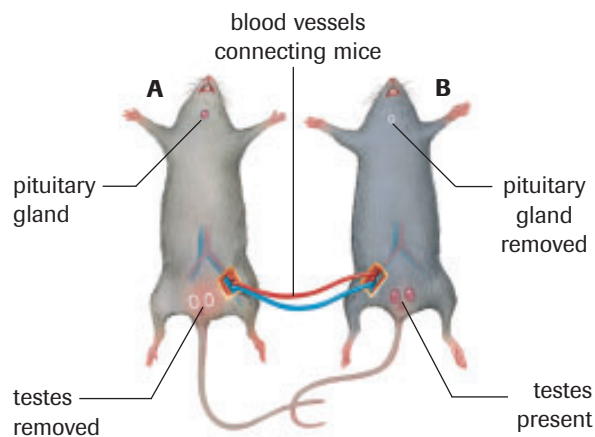


Figure 7
Circulatory systems of two mice are joined.

Report Checklist

- | | | |
|---|---|---|
| <input checked="" type="radio"/> Purpose | <input checked="" type="radio"/> Design | <input type="radio"/> Analysis |
| <input type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input checked="" type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input checked="" type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input type="radio"/> Evidence | |

Table 4 Presence of Hormones and Sperm in Joined Mice

Animal	Testosterone	LH	FSH	Sperm in urethra
A	+	+	+	–
B	+	+	+	+

- State the purpose of the experiment
- Write a hypothesis for the experiment.
- Write a design statement for the experiment. In your statement, identify one manipulated variable and one responding variable.

Evaluation

- Why were the circulatory systems joined?
- If LH and FSH are produced in the pituitary gland, explain how it is possible to find these hormones in mouse B.
- Explain why testosterone is found in both mice.

- (g) Why is sperm found in the urethra of mouse B but not in the urethra of mouse A?

Synthesis

- (h) In another experiment, the circulatory systems of the two mice were not joined and the data in **Table 5** were collected. Predict which glands and organs are present or absent from each animal. Give reasons for your prediction.

Table 5 Presence of Hormones and Sperm in Two Mice

Animal	Testosterone	LH	FSH	Sperm in urethra
A	—	+	+	—
B	—	—	—	—

SUMMARY

The Male Reproductive System

- The male reproductive system is composed of testes, seminiferous tubules, interstitial cells, Sertoli cells, epididymides, vasa deferentia, Cowper's glands, seminal vesicles, prostate gland, ejaculatory duct, urethra, and penis.
- The testes produce sperm cells and the male sex hormone, testosterone.
- Seminal fluids provide energy to the sperm and facilitate fertilization.
- The gonadotropic hormones FSH and LH are produced by the pituitary gland in response to GnRH from the hypothalamus.
- Sperm production is stimulated by FSH and testosterone.
- LH stimulates testosterone production in the testes.
- FSH, LH, and testosterone levels are regulated by negative feedback.
- High FSH levels stimulates production of inhibin, which lowers production of FSH by the pituitary and GnRH by the hypothalamus.
- High testosterone levels cause the hypothalamus to release less GnRH which, in turn, decreases production of LH. Decreased LH levels, in turn, leads to lower testosterone production.

► Section 16.1 Questions

1. Draw a diagram of the male reproductive system and label the following parts: penis, testis, urethra, seminiferous tubule, Cowper's gland, epididymis, prostate gland, vas deferens, seminal vesicle.
2. Describe the function of the following structures: Sertoli cells, seminiferous tubules, and epididymis.
3. Outline the functions of testosterone.
4. How do gonadotropic hormones regulate spermatogenesis and testosterone production?
5. What are the sources of energy for developing and mature sperm?
6. Using luteinizing hormone (LH) and testosterone as examples, explain how a negative feedback system works.
7. A vasectomy is a surgical procedure that blocks each vas deferens and keeps sperm from reaching the seminal fluid. The sperm are absorbed by the body instead of being ejaculated.
 - (a) Would a male who has had a vasectomy produce semen? Explain your answer.
 - (b) Would a male who has had a vasectomy continue to produce testosterone? Explain your answer.
 - (c) Why might this operation be performed?

16.2 The Female Reproductive System

ovum (*plural ova*) egg cell



CAREER CONNECTION

Diagnostic Medical Sonographer

Sonographers use ultrasound technology to assess the health of a woman's reproductive organs and to monitor pregnancies. They report their technical findings to physicians. Find out the entrance requirements for a program in medical sonography.

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In many ways, the female reproductive system (**Figure 1**) is more complicated than that of the male. Once sexual maturity is reached, males continue to produce sperm cells at a somewhat constant rate. In contrast, during their reproductive years, females follow a complicated sexual cycle, in which one **ovum** matures approximately every month.

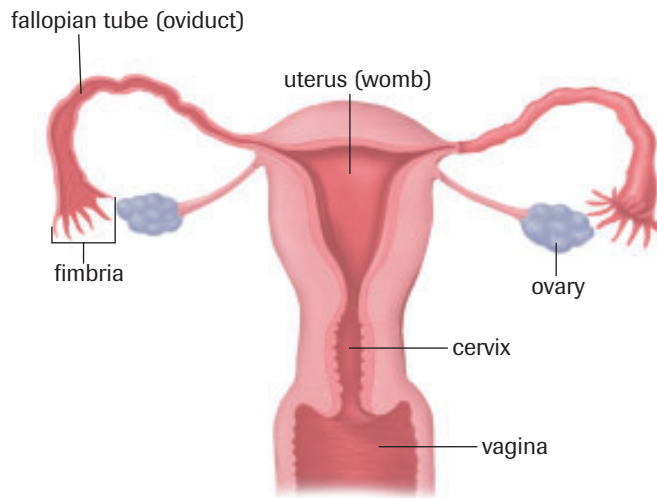


Figure 1
Female reproductive anatomy, frontal view.

As in males, secondary sexual characteristics begin to develop in females during puberty as a result of hormonal stimulation. In females, the development of breasts, widening of the hips, and the growth of hair in the armpits and pubis are linked with puberty (**Table 2**). These changes may occur very slowly and extend over a period of more than a decade, or they may appear rather suddenly and be completed within one or two years. While general social conditions, diet, and climate may affect the development, much of it is also determined by heredity.

Table 2 Secondary Sexual Characteristics in Females

<ul style="list-style-type: none"> • enlarged breasts • less facial hair than men • hair growth in armpits and pubis (crotch) • wider at the hips than at the shoulders • fat deposits around buttocks and hips 	<ul style="list-style-type: none"> • more body fat than men • hands and feet usually smaller and narrower than males • angle from thigh to ankle is slightly bent
--	--

During fetal development in the female, paired ovaries (flattened, olive-shaped organs) form in the same abdominal region as the testes in the male. Like the similarly shaped testes, the ovaries descend, but unlike the testes, which come to lie outside of the abdominal cavity, the ovaries remain in the pelvic region. At birth, **oocytes** (immature ova) are already present within the ovary.

oocyte an immature ovum

The **uterus** or **womb** is the largest organ in the female reproductive system. It is a muscular, hollow organ shaped like an inverted pear. The embryo and fetus develop in the uterus during normal pregnancies. The uterus is composed of two major tissues: a muscular outer lining and a glandular inner lining of the uterus, known as the **endometrium**.

The ovaries are connected to the uterus by two **Fallopian tubes** (Figure 1, previous page), named after Gabriello Fallopio, a 16th-century Italian anatomist. A Fallopian tube may also be called an **oviduct**. At the ends of each Fallopian tube are fingerlike projections called **fimbria** (singular, **fimbrium**). The uterus is connected to the outer environment by the **vagina**. Sexual intercourse occurs within the vagina, which also serves as the birth canal. The vagina is acidic, creating a hostile environment for microbes that might enter the female reproductive system. A muscular ring, called the **cervix**, separates the vagina from the uterus.

Cancer of the cervix is one of the major forms of cancer in females. Fortunately, early detection by a Pap test greatly improves the chances of curing this form of cancer. Like skin cells and the cells that line your mouth, cervical cells slough off. To collect a sample for a Pap test, a physician simply uses a swab to collect cells from the cervix. These cells are then checked for abnormalities that could indicate cancer.

Note that in females, the reproductive and excretory structures remain distinct. The urethra (the tube through which urine exits the body) of females is not connected to the reproductive organs. In males, the urethra provides a common pathway for sperm and urine to exit the body through the penis. A valve prevents both fluids from being released at the same time. However, the urethra of males is longer than that of females, which may account for the fact that females are more prone to bladder infections.

uterus (womb) the hollow, pear-shaped organ located between the bladder and the anus in females

endometrium the glandular inner lining of the uterus

Fallopian tube (oviduct) one of two tubes that connect the ovaries to the uterus

fimbrium (plural fimbria) a fingerlike projection at the end of a Fallopian tube

vagina the muscular canal extending from the cervix to the outer environment; the birth canal

cervix a muscular band that separates the vagina from the uterus



Simulation—Structures of the Female Reproductive System

In this activity, you will view a computer simulation of the structures of the female reproductive system. From the simulation, you will draw a diagram of the female reproductive system and label the following structures: vagina, ovaries, cervix, Fallopian tubes (oviducts), uterus, and endometrium.

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Oogenesis and Ovulation

The ovum is much larger than the male sex cell, the sperm (Figure 2). An ovum is packed with nutrients, so that when it is fertilized it can divide rapidly. Unlike males, who manufacture millions of sperm cells every day, usually only one ovum is produced in human females at a time.

As in sperm development, during its development, an oocyte undergoes a type of cell division that halves the number of chromosomes, from 46 chromosomes to 23. An ovum therefore has half as much genetic material as the original cell from which it developed. (You will learn about types of cell division in Unit 30 C).

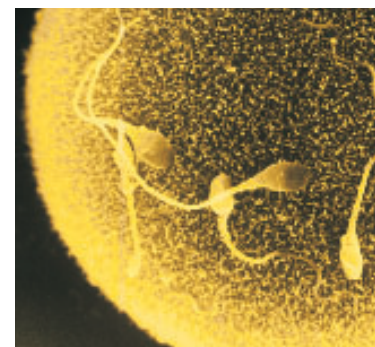


Figure 2

The male sperm cell is dwarfed by the much larger female egg cell. In humans, the egg cell is 100 000 times larger than the sperm cell.

oogenesis the formation and development of mature ova

follicle structure in the ovary that contains the oocyte

granulosa the layer of small cells that forms the wall of a follicle

Oogenesis is the formation of an ovum. In humans, oogenesis occurs in specialized cells in the ovaries, called **follicles** (Figure 3). A follicle contains two types of cells: a primary oocyte and cells of the granulosa. The **granulosa** is the layer of cells that forms the follicle wall. These cells provide nutrients for the developing oocytes.

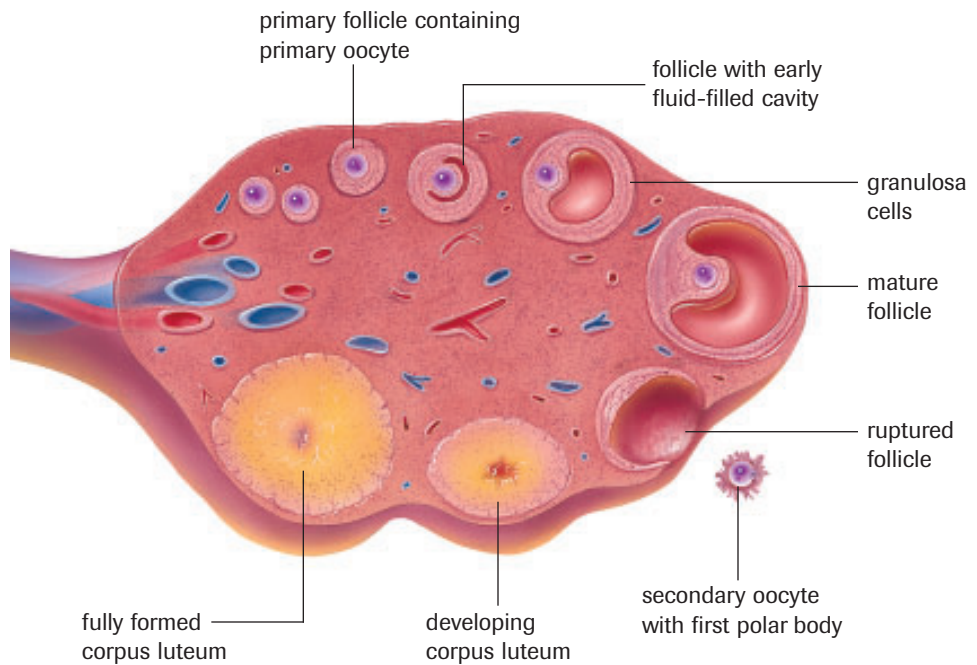



Figure 3  The process of ovulation. Pituitary hormones regulate the events of follicle development, ovulation, and the formation of the corpus luteum.

ovulation release of the secondary oocyte from the follicle held within the ovary

corpus luteum a mass of follicle cells that forms within the ovary after ovulation; secretes estrogen and progesterone

Oogenesis begins when nutrient follicle cells surrounding the primary oocyte begin to divide. As the primary oocyte undergoes cell division, the majority of cytoplasm and nutrients move to one of the end poles and form a secondary oocyte. The secondary oocyte contains 23 chromosomes. The remaining cell, referred to as the first polar body, receives little cytoplasm and dies. As the follicle cells surrounding the secondary oocyte proliferate, a fluid-filled cavity forms. Eventually, the dominant follicle pushes outward, ballooning the outer wall of the ovary. Constriction of blood vessels weakens the ovarian wall above the follicle, while enzymes weaken the wall of the follicle from the inside. The outer surface of the ovary wall bursts and the secondary oocyte is released. This process is referred to as **ovulation**. Surrounding follicle cells remain within the ovary and are transformed into the **corpus luteum**, which secretes hormones essential for pregnancy. If pregnancy does not occur, the corpus luteum degenerates after about 10 days.

Upon its release from the ovary, the secondary oocyte is swept into the funnel-shaped end of the Fallopian tube by the fimbria. The secondary oocyte is moved along the Fallopian tube by cilia where, if healthy sperm are present, it will become fertilized. The secondary oocyte will then undergo another unequal division of cytoplasm and nutrients and develop into the fertilized ovum. The cell that retains most of the cytoplasm and nutrients becomes the ovum, and the other cell becomes the second polar body, which deteriorates. If the secondary oocyte is not fertilized, it will deteriorate within 24 hours and die. When this occurs, the woman will undergo a menstrual cycle.

► Practice

1. What is the role of follicles in ovulation?
2. Describe how the corpus luteum forms in the ovary.

▶ mini Investigation

Microscopic Examination of the Ovary

Purpose

To view structures within the ovaries

Materials: lens paper, light microscope, prepared slides of ovary (cross-section), pencil

Visit the Nelson Web site to view micrographs of the ovary to help you to identify the structures on the prepared slides.

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- Using lens paper, clean the ocular and all the objective lenses of the microscope.
- Rotate the revolving nosepiece so that the low-power objective is in place.
- Position the prepared slide on the stage of the microscope and view the cross-section of the testes under low power.
- Centre the slide on a follicle and rotate the revolving nosepiece to the medium-power objective. Use only the fine adjustment to focus the cells.

- Is the follicle mature or immature?
- Diagram the follicle, and label any cell types that are visible, using **Figure 3**, on the previous page, as a guide.
 - Locate a second follicle that is at a different stage of development, and examine it under the medium-power objective.
- State whether this follicle is mature or immature, and draw and label it.
 - Find a mature follicle either on the same slide or another slide.
- Draw and label the mature follicle.
 - Locate a slide that shows the corpus luteum. Find and view this structure.
- Draw and label the corpus luteum.
- Organize your diagrams to reflect the process of ovulation. Explain the reasons behind your sequence of diagrams.

WWW WEB Activity

Case Study—Tubal Ligation

Similar to vasectomy in males, tubal ligation is a surgical method of female sterilization. As its name suggests, during tubal ligation, the surgeon cuts and then ties off the Fallopian tubes.

Figure 4 shows the Pomeroy technique for a tubal ligation, which can be reversed.

Approximately 60 % of the women who have had the procedure reversed become pregnant.

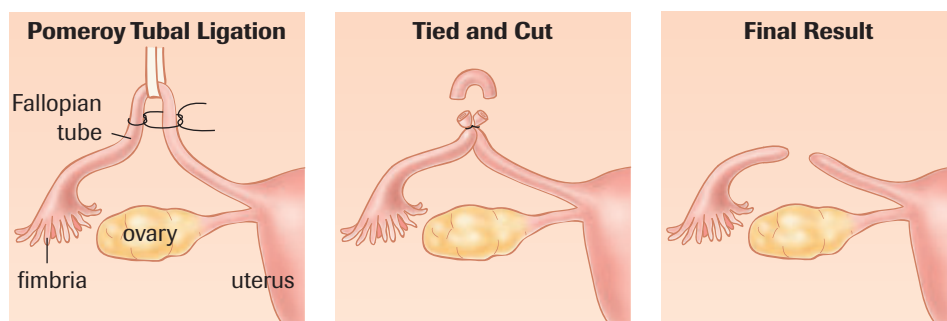


Figure 4

The Pomeroy method of tubal ligation is reversible in up to 60 % of cases.

In this Web Activity, you will find out more about the Pomeroy procedure and its reversal. You may also find out about other technologies that can be used to prevent pregnancy.

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Menstrual Cycle

Along with the development of secondary sexual characteristics, puberty also initiates the **menstrual cycle**, which includes oogenesis, ovulation, and thickening and shedding of the endometrium. The menstrual cycle lasts an average of 28 days (although variation in this cycle is common) and is repeated throughout a woman's reproductive lifetime. The cycle is regulated by changes in the levels of various hormones.

The menstrual cycle can be divided into four distinct phases: flow phase, follicular phase, ovulatory phase, and luteal phase (**Figure 5**). Shedding of the endometrium, or **menstruation**, marks the **flow phase**. This is the only phase of the female reproductive cycle that can be determined externally. For this reason, the flow phase is used to mark the beginning of the menstrual cycle. Approximately five days are required for the uterus to shed the endometrium.

The **follicular phase** is characterized by the development of follicles within the ovary. As follicles develop, the hormone **estrogen** is secreted, increasing the estrogen concentration in the blood. The follicular phase normally takes place between days 6 and 13 of the female menstrual cycle.

During the **ovulatory phase**, the third phase of the female menstrual cycle, the secondary oocyte bursts from the ovary and follicular cells differentiate into the corpus luteum. The development of the corpus luteum marks the beginning of the **luteal phase**.

menstruation (flow phase) the shedding of the endometrium during the menstrual cycle

follicular phase phase marked by development of ovarian follicles before ovulation

estrogen hormone that activates development of female secondary sex characteristics, and increased thickening of the endometrium during the menstrual cycle

ovulatory phase phase in which ovulation occurs

luteal phase phase of the menstrual cycle characterized by the formation of the corpus luteum following ovulation

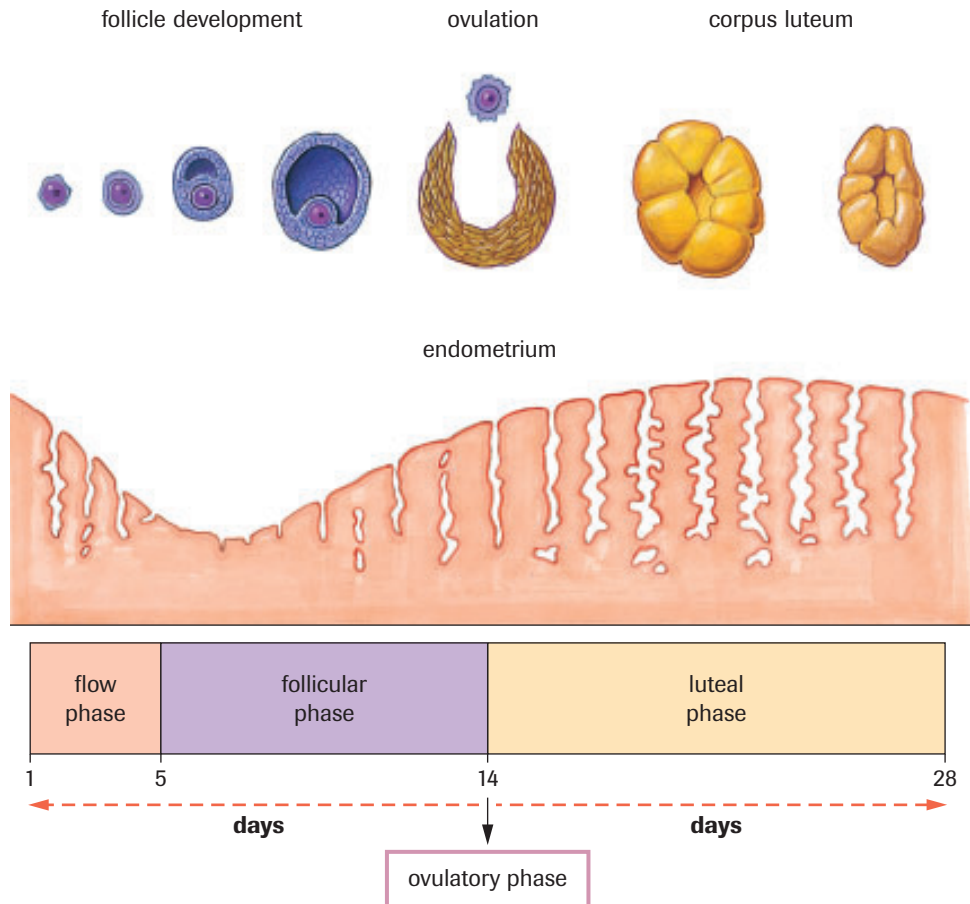


Figure 5

The thickness of the endometrium increases from the beginning of the follicular phase to the end of the luteal phase. The development of blood vessels and glandular tissues helps prepare the uterus for a developing embryo. Should no embryo enter the uterus, menstruation occurs, and the menstrual cycle begins again.

Estrogen levels begin to decline when the oocyte leaves the ovary, but are somewhat restored when the corpus luteum forms. The corpus luteum secretes both estrogen and **progesterone**. Progesterone continues to stimulate the endometrium and prepares the uterus for an embryo. It also inhibits further ovulation, prevents uterine contractions, and firms the cervix to prevent expulsion of the fetus. The luteal phase, which occurs between days 15 and 28, prepares the uterus to receive a fertilized egg. Should fertilization of an ovum not occur, the concentrations of estrogen and progesterone will decrease, thereby causing uterine contractions. These uterine contractions make the endometrium pull away from the uterine wall. The shedding of the endometrium marks the beginning of the next flow phase, and the female menstrual cycle starts all over again. This cycle is summarized in **Table 2**.

Table 2 The Female Menstrual Cycle

Phase	Description of events	Hormone produced	Days
flow	• menstruation		1–5
follicular	• follicles develop in ovaries • endometrium is restored	estrogen produced by follicle cells	6–13
ovulation	• oocyte bursts from ovary		14
luteal	• corpus luteum forms and endometrium thickens	estrogen and progesterone produced by the corpus luteum	15–28

Unlike the testes, which replenish sex cells, the female ovaries undergo continual decline after the onset of puberty. Each of the two ovaries contains about 400 000 follicles at puberty. Many follicles develop during each female reproductive cycle, but usually only a single follicle becomes dominant and reaches maturity. The remaining follicles deteriorate and are reabsorbed within the ovary. Between the ages of about 12 and 50 in a woman's life, approximately 400 eggs will mature. By the time a woman reaches **menopause**, when ovulation ceases, few follicles remain. It has been suggested that the higher incidence of genetic defects in children produced by older women can be linked to the age of the follicles. Older follicles are presumed to have a greater chance of genetic damage. Because female sex hormones are produced within the ovary, menopause marks the end of a female's reproductive life and signals a drop in the production of female hormones.

Feedback Control of the Menstrual Cycle

The hypothalamus–pituitary complex regulates the production of estrogen and progesterone, the hormones of the ovary. In females, the gonadotropins **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH)** regulate the control of hormones produced by the ovaries: estrogen and progesterone. In turn, ovarian hormones, as part of a complex negative feedback mechanism, regulate the gonadotropins.

The onset of female puberty is signalled by the release of GnRH (gonadotropin-releasing hormone) from the hypothalamus (**Figure 6**). GnRH activates the pituitary gland, which is the production and storage site of FSH and LH. During the follicular phase of the menstrual cycle, the blood carries FSH secretions to the ovary, where follicle development is stimulated. The follicles within the ovary secrete estrogen, which initiates the development of the endometrium. As estrogen levels rise, a negative feedback message is sent to the pituitary gland to turn off secretions of FSH. The follicular phase of the menstrual cycle has ended. Simultaneously, the rise in estrogen stimulates the LH-producing cells of the pituitary gland. LH secretion rises dramatically and ovulation occurs.

progesterone hormone produced primarily by the corpus luteum, that induces changes in the endometrium during the menstrual cycle

menopause the termination of the female reproductive years

follicle-stimulating hormone (FSH) in females, a gonadotropin that promotes the development of the follicles in the ovary

luteinizing hormone (LH) in females, a gonadotropin that promotes ovulation and the formation of the corpus luteum

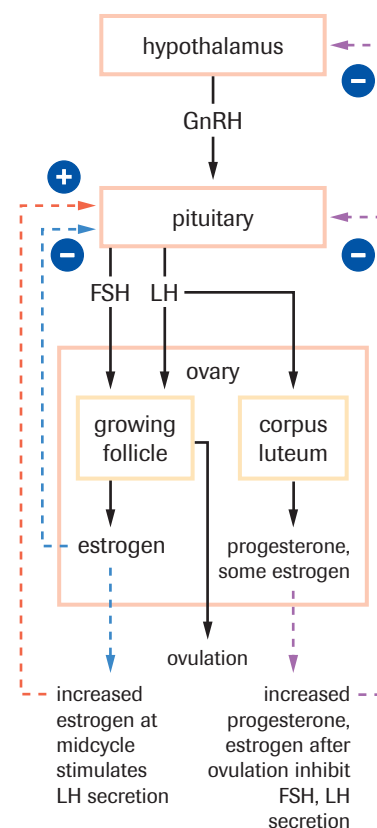


Figure 6 Feedback loop showing the regulation of ovarian hormones

DID YOU KNOW?

Menopause Is a Major Transition

When a middle-aged woman has missed her menstrual period for 12 consecutive months, she has officially reached menopause. By that point, estrogen levels have dropped by as much as 90 % from their lifetime high.

+ EXTENSION

CBC radio ONE

QUIRKS & QUARKS

A Woman's Dilemma: The Benefits and Risks of HRT

Alicia Priest (medical journalist in Victoria), Heather Davies (61-year-old Victoria woman and former nurse), Dr. Christine Derzko (leading authority on HRT and an associate professor of obstetrics and gynaecology at the University of Toronto), Dr. Nanette Wenger (cardiologist at Atlanta's Emory University), and Dr. Jerilyn Prior, (professor of endocrinology at the University of B.C.) discuss the benefits and risks of estrogen and HRT for menopausal women, including recent research results that show the treatment may not be as safe as earlier presumed.

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After ovulation, the remaining follicular cells, under the influence of LH, are transformed into a functioning corpus luteum. The luteal phase of the menstrual cycle has begun. Cells of the corpus luteum secrete both estrogen and progesterone. The buildup of estrogen and progesterone will further increase the development of the endometrium. As progesterone and estrogen build up within the body, a second negative feedback mechanism is activated. Progesterone and estrogen work together to inhibit the release of both FSH and LH. Without gonadotropic hormones, the corpus luteum begins to deteriorate, slowing estrogen and progesterone production. The drop in ovarian hormones signals the beginning of menstruation. Some birth control pills (also called oral contraceptives) contain high concentrations of progesterone, which inhibits ovulation and thereby prevents conception.

Hormones involved in the menstrual cycle and their roles are summarized in **Table 3**.

Table 3 Female Reproductive Hormones

Hormone	Location	Description of function
estrogen	follicle cells (ovary)	inhibits growth of facial hair, initiates secondary sexual characteristics, and causes thickening of the endometrium
progesterone	corpus luteum (ovary)	inhibits ovulation, inhibits uterine contractions, firms the cervix, and stimulates the endometrium
follicle-stimulating hormone (FSH)	pituitary	stimulates the development of the follicle cells in the ovary
luteinizing hormone (LH)	pituitary	stimulates ovulation and the formation and maintenance of the corpus luteum

You may recall from the previous section that LH and FSH are also involved in regulation of the male reproductive system. Similarities between male and female systems extend beyond this. Testosterone and estrogen can be produced by either sex. Male characteristics result because the levels of male hormones exceed the levels of estrogen. Males are ensured of maintaining low levels of female hormones by excreting them at an accelerated rate. This may explain why the urine of a stallion contains high levels of estrogen. In humans, the secretions of male hormones will stimulate the development of the male's prostate gland, but injections of estrogen will slow the process. This may explain why cancerous tumours of the prostate can be slowed by injections of estrogen-like compounds.

► Practice

3. Outline the functions of estrogen and progesterone.
4. How do gonadotropic hormones regulate the function of ovarian hormones?



LAB EXERCISE 16.B

Hormone Levels during the Menstrual Cycle

How do hormone levels regulate the female menstrual cycle? Use the following experimental data to analyze hormone levels during the menstrual cycle.

Analysis and Evaluation

- Gonadotropic hormones regulate ovarian hormones. Study the feedback loop shown in **Figure 7**.
 - Which of the four hormones (W, X, Y, and Z) are gonadotropic hormones?
 - Which of the four hormones are ovarian hormones?
 - Which of the four hormones exert negative feedback effects?

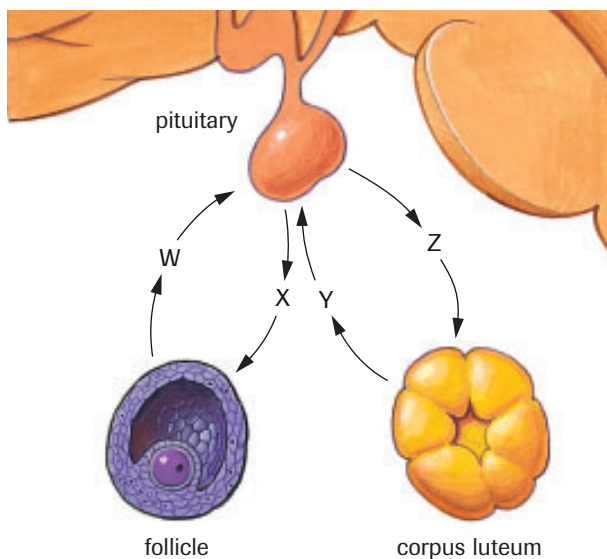


Figure 7

Feedback loop showing the regulation of gonadotropic and ovarian hormones.

- Body temperatures of two women were monitored during their menstrual cycles. One woman ovulated; the other did not. The results are shown in **Table 4**.
 - Graph the data in **Table 4**.
 - Assuming this menstrual cycle represents the average 28-day cycle, label the ovulation day on the graph.
 - Describe changes in temperature before and during ovulation.
 - Compare body temperatures with and without a functioning corpus luteum.

Report Checklist

- | | | |
|----------------------------------|---------------------------------|---|
| <input type="radio"/> Purpose | <input type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input type="radio"/> Evidence | |

Table 4 Temperature Changes in an Ovulating Woman and a Non-Ovulating Woman

Days	Temperature (°C)	
	Ovulation occurs	No ovulation
5	36.4	36.3
10	36.2	35.7
12	36.0	35.8
14	38.4	36.2
16	37.1	36.1
18	36.6	36.0
20	36.8	36.3
22	37.0	36.3
24	37.1	36.4
28	36.6	36.5

- Figure 8** shows changes in the thickness of the endometrium throughout the menstrual cycle.
 - Identify the events that occur at times X and Z.

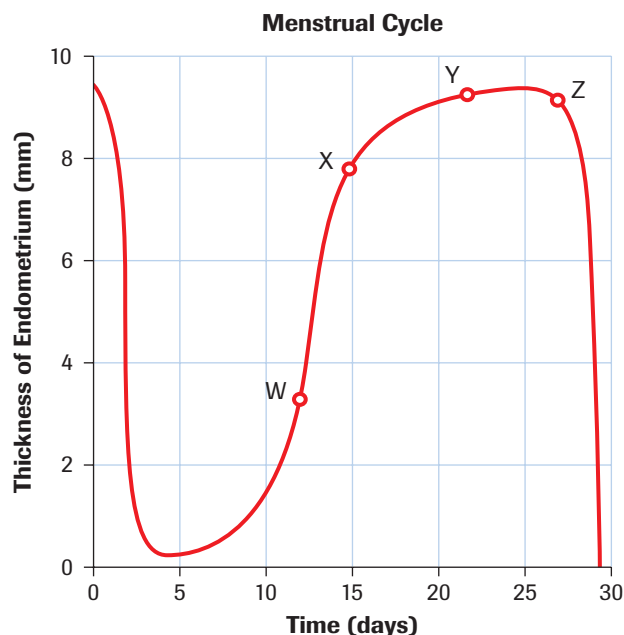


Figure 8

Changes in the thickness of the endometrium during the menstrual cycle

LAB EXERCISE 16.B *continued*

- (i) Identify by letter the time at which follicle cells produce estrogen.
- (j) Identify by letter the time at which the corpus luteum produces estrogen and progesterone.
4. Levels of gonadotropic hormones monitored throughout the reproductive cycle are shown in **Figure 9**. Levels are recorded in relative units.
- (k) How does LH affect estrogen and progesterone?

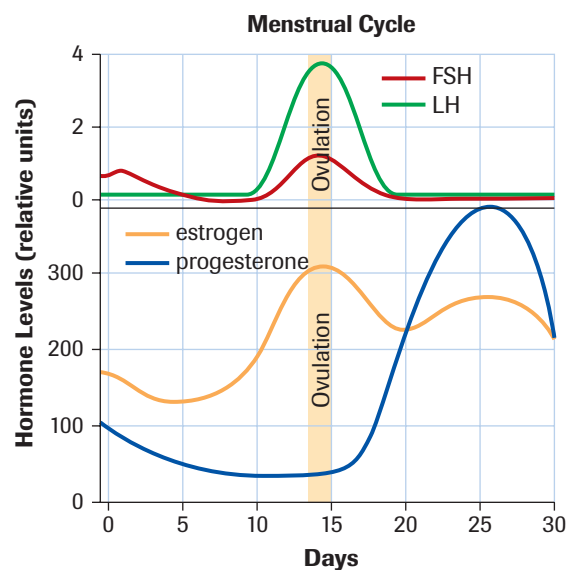


Figure 9
Changes in estrogen and progesterone during the menstrual cycle

SUMMARY

The Female Reproductive System

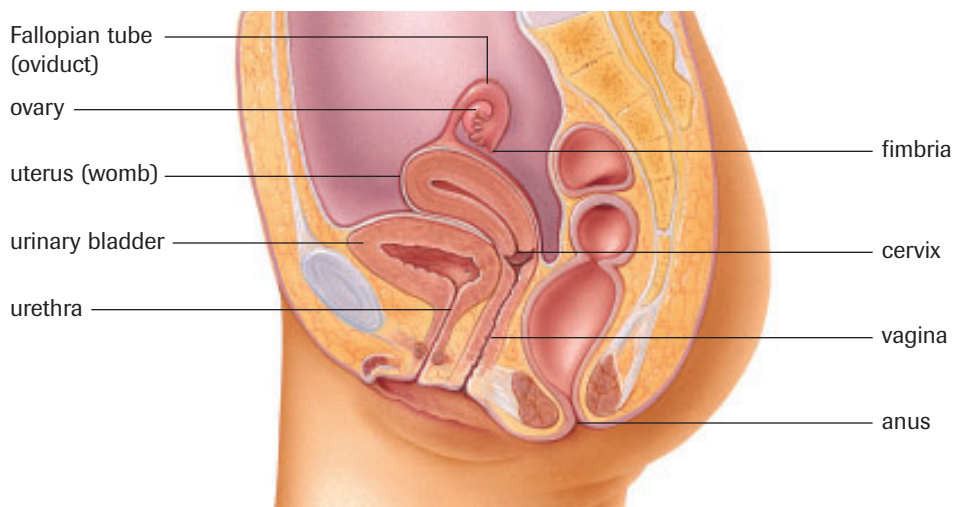


Figure 10
Female reproductive anatomy, side view. Note there are two oviducts and two ovaries. **Table 5** on the next page summarizes the structures and functions of the female reproductive system.

Table 5 The Female Reproductive System

Structure	Function
ovaries	<ul style="list-style-type: none"> produce the hormones estrogen and progesterone site of ovum (egg cell) development and ovulation
Fallopian tubes (oviducts)	<ul style="list-style-type: none"> carry the ovum from the ovary to the uterus usually the site of fertilization
fimbriae	<ul style="list-style-type: none"> sweep the ovum into the Fallopian tube following ovulation
uterus (womb)	<ul style="list-style-type: none"> pear-shaped organ in which the embryo and fetus develop involved in menstruation
cervix	<ul style="list-style-type: none"> separates the vagina from the uterus holds the fetus in place during pregnancy dilates during birth to allow the fetus to leave the uterus
vagina	<ul style="list-style-type: none"> extends from the cervix to the external environment provides a passageway for sperm and menstrual flow functions as the birth canal

- Oogenesis the process by which an ovum matures within a follicle. Oogenesis is stimulated by FSH (follicle stimulating hormone).
- Ovulation involves the release of the egg from the follicle, and is stimulated by LH (leutenizing hormone).
- Menstruation is the shedding of the endometrium, and marks the beginning of the menstrual cycle.
- During the menstrual cycle, levels of estrogen and progesterone change. Estrogen stimulates thickening of the endometrium. Progesterone inhibits ovulation and uterine contractions, firms the cervix, and stimulates the endometrium.

+ EXTENSION

The Estrous Cycle

Mammals vary greatly in the detailed functioning of their reproductive systems. Complete this extension activity to compare the human menstrual cycle to the estrous cycle, which occurs in mammals such as dogs, cattle, and bears.

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► Section 16.2 Questions

- Describe the process of ovulation. Differentiate between primary oocytes, secondary oocytes, and ova.
- Describe the events associated with the flow phase, follicular phase, and luteal phase of menstruation.
- With reference to the female reproductive system, provide an example of a negative feedback control system.
- Predict how low secretions of gonadotropin-releasing hormone (GnRH) from the hypothalamus would affect the female menstrual cycle.
- What is a Pap smear?
- Tubal ligation, ties the Fallopian tubes as a method of female sterilization.
 - Why would a woman who has undergone this procedure be unable to get pregnant? Explain your answer.
 - Would a woman who undergoes a tubal ligation still menstruate?
- Explain why birth control pills often contain high concentrations of progesterone and estrogen.
- Explain why only one corpus luteum may be found in the ovaries of a woman who has given birth to triplets.
- Estrogen plays a crucial role in maintaining bone strength and density. This is why women over age 50 and women who experience premature menopause are at risk for developing osteoporosis, a disease characterized by low bone mass and increased bone fragility. What can be done to minimize this risk? Investigate both hormone therapies and lifestyle factors.
- Cattle are given various steroid hormones to increase meat production. Recently, some scientists have expressed concern that animal growth stimulators might have an effect on humans. State and justify your opinion on the practice of using hormones in cattle. What potential problems in humans might be associated with such procedures?

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16.3 Fertilization, Pregnancy, and Birth

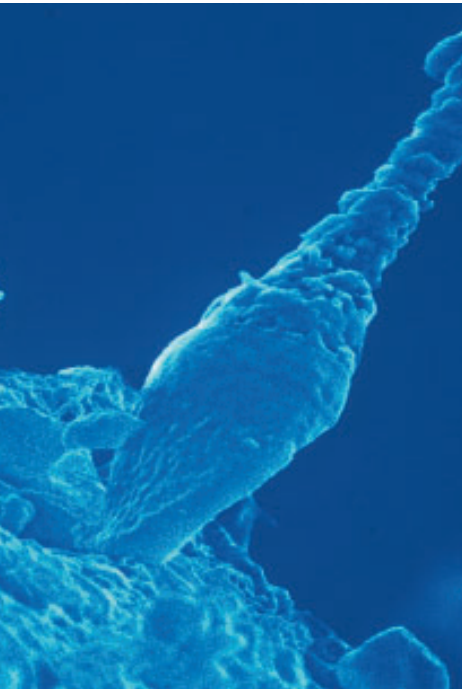


Figure 1
Human sperm cell attached to ovum

cleavage cell division of a zygote, in which the number of cells increases without any change in the size of the zygote

blastocyst an early stage of embryo development

implantation the attachment of the embryo to the endometrium

Fertilization in humans occurs in a Fallopian tube, and involves the union of a sperm cell with a secondary oocyte. The secondary oocyte then completes its development to become the fertilized ovum (zygote). The zygote receives 23 chromosomes from the sperm cell and 23 chromosomes from the oocyte, and so has 46 chromosomes. Between 150 million and 300 million sperm cells of the 500 million ejaculated during intercourse will travel through the cervix into the uterus. However, only a few hundred actually reach the Fallopian tubes. Although several sperm become attached to the outer edge of the ovulated oocyte, only a single sperm cell fuses with it (**Figure 1**).

The length of time required for the fertilized ovum to travel the 10 to 12 cm Fallopian tube to the uterus is between three and five days. During this time, it undergoes many cell divisions in a process called cleavage. **Cleavage** involves equal divisions of the cells of the zygote without any increase in size (**Figure 2 (a)**). As a result, the cells of the zygote become progressively smaller with each division. By the time it reaches the uterus, in about six days, the zygote has developed into a fluid-filled structure called a blastocyst (**Figure 2 (b)**). The **blastocyst** consists of an outer sphere of cells, from which the extraembryonic structures develop, and an inner cell mass, from which the embryo develops. Once in the uterus, the blastocyst becomes attached to the wall of the endometrium, a process referred to as **implantation**.

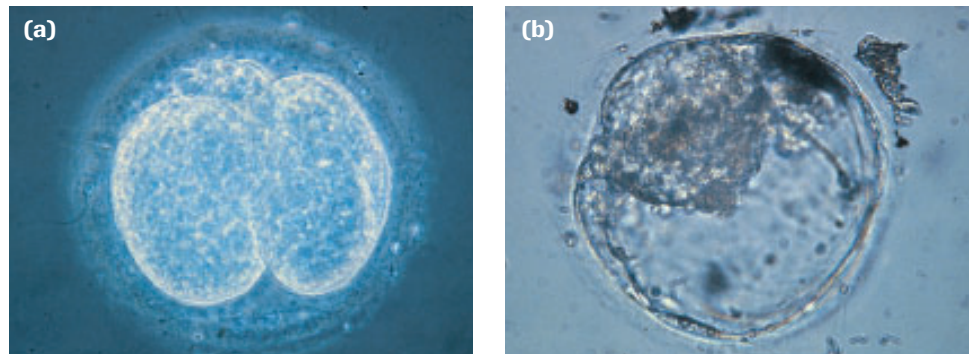


Figure 2
(a) Two-cell stage of a human zygote undergoing cleavage
(b) Blastocyst after 4 to 6 days

+ EXTENSION

Blocking Polyspermy

What prevents more than one sperm from fertilizing the ovum (polyspermy)? This Audio Clip outlines the sequence of actions that are associated with preventing polyspermy.

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Changes in the Female Reproductive System

In humans, four days after fertilization, the zygote becomes an embryo. It will remain an embryo until the end of the eighth week of pregnancy, after which time it is referred to as a fetus. The events of pregnancy, usually take place over about nine months from the woman's last menstrual period. Over this time, a woman's body will change to ensure the pregnancy continues and the embryo/fetus is protected. Some of these changes are shown in **Figure 3** on the next page.

For pregnancy to continue, menstruation cannot occur. Any shedding of the endometrium would mean the dislodging of the embryo from the uterus. However, maintaining the endometrium presents a problem for the hormonal system. To prevent menstruation, progesterone and estrogen levels must be maintained. High levels of these hormones have a negative-feedback effect on the secretion of gonadotropic hormones.

LH levels must remain high to sustain the corpus luteum. Should the corpus luteum deteriorate, the levels of estrogen and progesterone would drop, stimulating uterine contractions and the shedding of the endometrium.

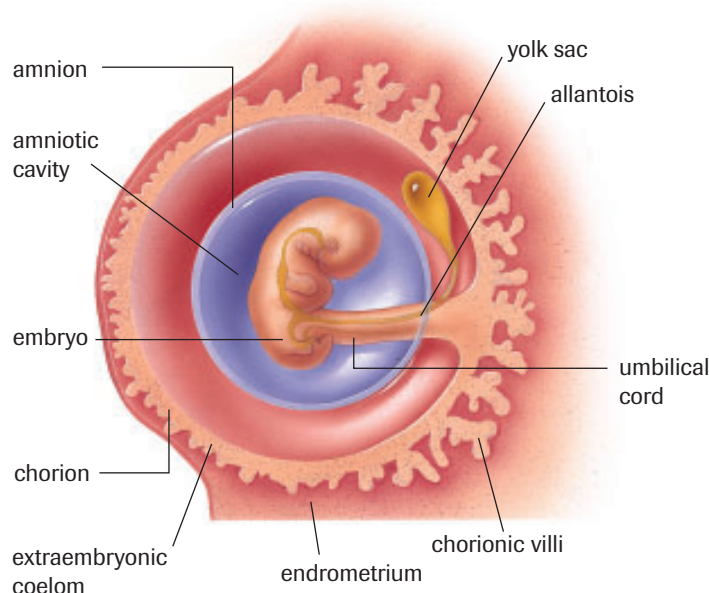


Figure 3
Structures that support the developing embryo at 4 weeks

This problem is avoided by secretion of hormone from the blastocyst itself. The outer layer of the blastocyst gives rise to two structures: the **chorion** and the **amnion**. The chorion produces the hormone **human chorionic gonadotropin hormone (hCG)**, which maintains the corpus luteum for the first three months of pregnancy. The functioning corpus luteum continues producing progesterone and estrogen, which in turn maintain the endometrium. The endometrium and embryo thus remain in the uterus. Pregnancy tests identify hCG levels in the urine of women.

Between the amnion and the embryo or fetus is the **amniotic cavity**, a fluid-filled sac that insulates the embryo, and later the fetus, protecting it from infection, dehydration, impact, and changes in temperature. The **extraembryonic coelom** is a fluid-filled space between the amnion and the chorion. By the second week of pregnancy, the **yolk sac** forms beneath the embryo. The yolk sac is the site of early red blood cell formation and later contributes to the primitive digestive tract.

Cells from the embryo and endometrium combine to form the **placenta**, through which materials are exchanged between the mother and developing embryo. At approximately the fourth month of pregnancy, the placenta begins to produce estrogen and progesterone. High levels of progesterone prevent further ovulation. This means that once a woman is pregnant, she cannot become pregnant again during that pregnancy.

The placenta is richly supplied with blood vessels. Projections called **chorionic villi** ensure that a large number of blood vessels of the fetus are exposed to maternal blood. The **allantois**, provides umbilical blood vessels in the placenta. However, unlike the chorion and amnion, the allantois does not envelop the fetus. The placenta provides an interface for exchange between mother and fetus. Nutrients and oxygen diffuse from the mother's blood into the blood of the developing fetus. Wastes diffuse in the opposite direction, moving from the fetus to the mother. The **umbilical cord** connects the embryo with the placenta (Figure 4, next page).

+ EXTENSION



Cleavage and Implantation

This animation shows events that happen in the female reproductive system from fertilization of the egg to formation of the chorion.

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chorion the outer extraembryonic structure of a developing embryo that will contribute to the placenta

amnion a fluid-filled extraembryonic structure

human chorionic gonadotropin hormone (hCG) an embryonic hormone that maintains the corpus luteum

amniotic cavity the fluid-filled cavity surrounding the developing embryo

extraembryonic coelom body cavity between the amnion and the chorion

yolk sac a membranous sac that forms during embryo development of most vertebrates; in humans, it does not contain yolk

placenta the site for the exchange of nutrients and wastes between mother and fetus

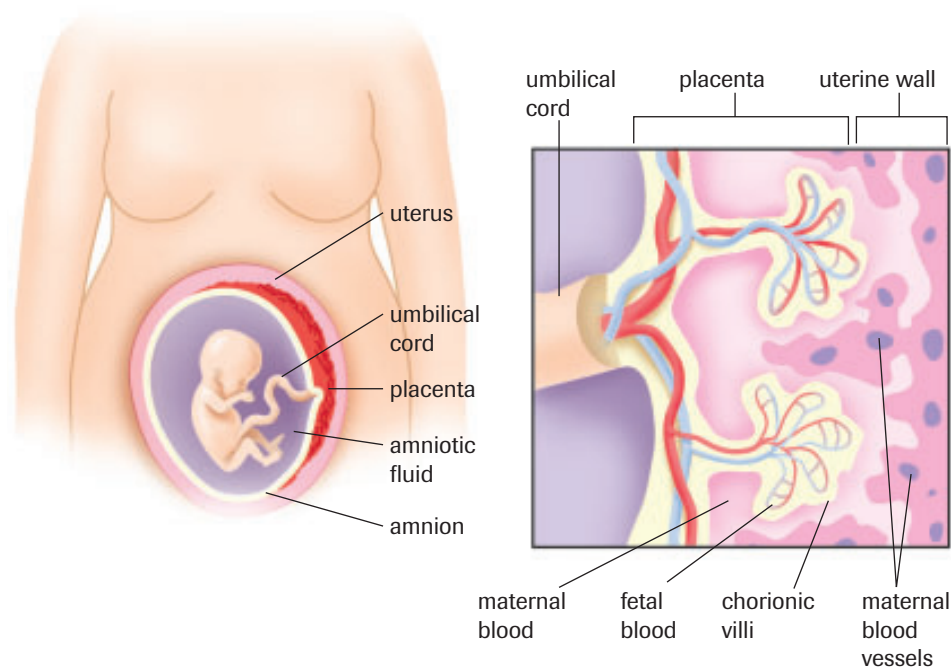
chorionic villi vascular projections of the chorion

allantois extraembryonic structure that contributes to the blood vessels of the placenta

umbilical cord structure that connects the fetus to the placenta

Figure 4 

The developing fetus is nourished by the placenta. The rich supply of blood vessels allows for exchange of nutrients, oxygen, and waste between the maternal blood supply and the fetal blood supply.



► Practice

1. Using a diagram, differentiate between the allantois and the amnion. What are their functions?

Embryonic and Fetal Development

Morphogenesis is the development of an organism or part of it. Morphogenesis in humans and other multicellular organisms involves two processes: growth (increase in size) and differentiation (cell specialization). In this section, we will explore the morphogenesis that takes place during pregnancy.

The nine months of pregnancy are divided into three trimesters. The **first trimester** extends from fertilization to the end of the third month. By the second week of development, the inner cells of the blastula have reorganized into a flattened disk made up of two layers. **Gastrulation** is the process in which the two-layered structure develops into a three-layered structure called a **gastrula**. Gastrulation is a very important developmental step. Each of these three layers has a particular developmental fate. In other words, each layer will give rise to specific organs and structures in the fetus. These are shown in **Table 1**.

Table 1 Organs and Structures Arising from the Three Gastrula Layers

Gastrula layer	Structures
ectoderm	<ul style="list-style-type: none"> • skin, hair, finger nails, sweat glands • nervous system, brain, peripheral nerves • lens, retina, cornea • inner ear, cochlea, semicircular canals • teeth, inside lining of mouth
mesoderm	<ul style="list-style-type: none"> • muscles (skeletal, cardiac, and smooth) • blood vessels and blood • kidneys, reproductive structures • connective tissue, cartilage, bone
endoderm	<ul style="list-style-type: none"> • liver, pancreas, thyroid, parathyroid • urinary bladder • lining of digestive system • lining of respiratory tract

first trimester the period during pregnancy from conception until the end of the third month

gastrulation process by which a gastrula is formed

gastrula stage of embryonic development in which the embryo is composed of three layers: ectoderm, mesoderm, and endoderm

Gastrulation begins when the disk elongates and forms a narrow line of cells at the midline. Cells migrate inward near this line and differentiate into the three layers of the gastrula. The outer layer is the **ectoderm**, the middle layer is the **mesoderm**, and the inner layer is the **endoderm**.

By the end of the first month, the 1 cm long embryo is 500 times larger than the fertilized egg (**Table 2** on page 534, **Figure 5 (a)**). Many of the important organs and systems are beginning to develop by this point. The four-chambered heart has formed, a large brain is visible, and limb buds with tiny fingers and toes have developed. By the ninth week (**Figure 5 (b)**), the embryo is referred to as a fetus. Arms and legs begin to move and a sucking reflex is evident.

By the beginning of the **second trimester**, the fetus is about 8 cm long and all of its organs have formed, although they are not fully developed. During this trimester, the organs continue to develop and the fetus increases in size. It will move enough to make itself known to the mother and it begins to look more like a human infant (**Figure 5 (c)**). As in other mammals, soft hair begins to cover the entire body. By the sixth month, eyelids and eyelashes form. Most of the cartilage that formed the skeleton has been replaced by bone cells. Should the mother go into labour at the end of the second trimester, there is a chance that the 34 cm, 1000 g fetus will survive.

During the **third trimester**, the baby grows rapidly (**Figure 5 (d)**). Organ systems have been established during the first two trimesters; all that remains is for the body mass to increase and the organs to enlarge and become more developed. At birth, the average human infant is approximately 51 cm long and weighs about 3400 g.

Table 2, on the next page, outlines the major events in human embryo development.

+ EXTENSION



Weeks 3 to 4 of Development

This animation shows early events in organ formation during development of a human embryo.

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ectoderm the outer layer of cells in an embryo

mesoderm the middle layer of cells in an embryo

endoderm the inner layer of cells in an embryo

second trimester the period during pregnancy from the fourth month to the end of the sixth month

third trimester the period during pregnancy from the seventh month until birth

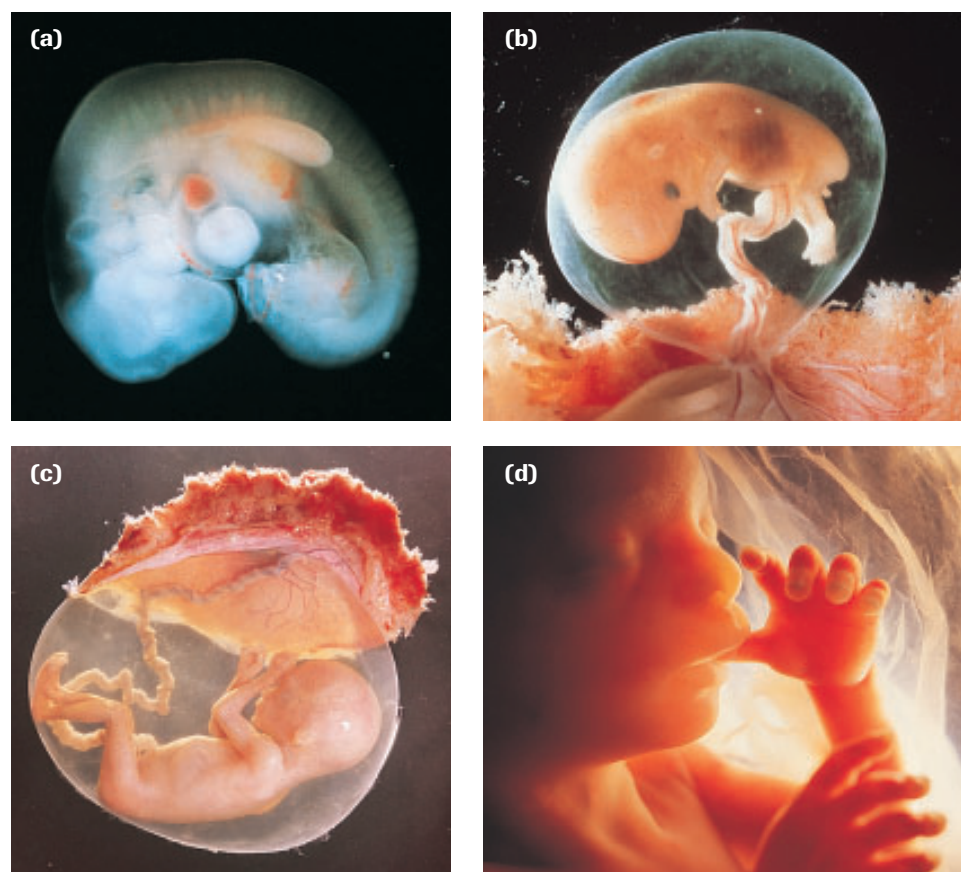








Figure 5

- (a) Human embryo at 4 weeks
- (b) Fetus at 9 weeks
- (c) Fetus at 16 weeks
- (d) Fetus at 18 weeks

Table 2 Three Stages of Development

Stage	Characteristics	
First Trimester		
0–1.5 weeks	<ul style="list-style-type: none"> fertilization and early development formation of a viable zygote by the union of sperm and ovum; fertilization implantation normally positioned in the uterus 	
1.5 weeks	<ul style="list-style-type: none"> embryonic development begins amnion and yolk sac formed 	
2nd week	<ul style="list-style-type: none"> formation of primitive streak and primary germ layers 	
3rd week	<ul style="list-style-type: none"> central nervous system begins to develop heart development initiated; beating begins 	
4th week	<ul style="list-style-type: none"> about 1 cm long and weighs less than 1 g early eyes limb buds of arms and legs 	
5th week	<ul style="list-style-type: none"> nose and lips formation begins basic architecture of brain and spinal cord established 	
8th week	<ul style="list-style-type: none"> now about the size of a chicken's egg embryo 2 cm long and weighs about 4 g hands and feet seen baby extremely reactive to its environment male sex hormone (testosterone) produced by testes masculine development in males; no change in females 	
9th week	<ul style="list-style-type: none"> fetal development begins 	
12th week	<ul style="list-style-type: none"> embryo about the size of a goose egg placenta well-established and weighs more than the baby baby approximately 9 cm long and weighs about 60 g 	
Second Trimester		
14th–16th week	<ul style="list-style-type: none"> brain developed to the point that baby can suck, swallow, and make irregular breathing movements 	
16th week	<ul style="list-style-type: none"> 14 cm long and weighs 180 g complete closure of nasal septum and palate fetal heart beat heard with amplification fetal movement is recognized sex distinguishable now 	
20th week	<ul style="list-style-type: none"> 20 cm long and weighs 300 g fine hair covering over entire body; probably for protection of skin fetal heart beat heard: 120–160 beats per minute 	
Third Trimester		
28th week	<ul style="list-style-type: none"> baby can survive outside uterus if lungs capable of breathing 10 %–20 % survival if born at this time 35 cm long and weighs 1100 g 	
32nd week	<ul style="list-style-type: none"> maturing: 50 % survival if born at this time should turn to head down position 41 cm long, weighs 1680 g skin red and wrinkly 	
30th–34th week	<ul style="list-style-type: none"> baby the same size as placenta 	
36th week	<ul style="list-style-type: none"> 94 % survival rate if born at this age 46 cm long, weighs 2500 g some subcutaneous fat fingerprints now at the tips of the fingers 	
40th week	<ul style="list-style-type: none"> full term: 51 cm long, weighs 3400 g 	



Simulation—The Visible Embryo

A zygote is formed by the union of a sperm cell and an egg cell. In humans, the single fertilized egg cell is transformed into a multicellular embryo by cell division. During embryonic development, cells become specialized and begin to form organs and organ systems.

In this Web Activity, you will examine the changes that occur during embryonic development. Week 1 describes fertilization and cleavage, week 2 implantation, and week 3 the process of gastrulation. Week 4 presents photos and descriptions of folding and tissue formation. Each section includes self quizzes to assist in you in learning more about embryonic development.

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Human Sex Determination

Sex is determined by the genetic makeup of the fetus. Females have two X chromosomes, while males have a single X and a much smaller Y chromosome. You will find out more about X and Y chromosomes in Unit 30 C. In 1987, geneticists were able to locate the principal gene for sex determination on the Y chromosome. The *SRY* (Sex-determining Region of the Y chromosome) gene is mainly responsible for determining the male phenotype in humans. It might surprise you to find out that a male fetus does not differ from a female fetus until about the sixth or seventh week of pregnancy. In the presence of the *SRY* gene, the developing gonad becomes a testis. Synthesis of hormones by cells of the testis subsequently directs the development of male characteristics. The testes develop inside the body cavity in the same location as the ovaries and gradually descend. It may appear that the absence of the *SRY* gene causes the development of the female characteristics. However, things may not be quite this simple. Some researchers have speculated that female sex determination might be even more complicated than that of the male.

The balance between male and female is also determined by the hormones circulating in the bloodstream. Women produce some male sex hormones or androgens, along with estrogen. A woman's body will synthesize estrogen from androgens such as testosterone. Similarly, males produce female sex hormones, but in much smaller quantities than females do.

At no time is the hormonal balance between male and female sex hormones more critical than during fetal development. Too much estrogen at the wrong time can transform an organism with male genes into what outwardly appears to be a female. Conversely, an overabundance of androgens or male sex hormones during fetal development can produce the sex organs of a male in the genetic body of a female.

DID YOU KNOW?

Environmental Estrogens

Many widely used synthetic chemicals and natural plant compounds can alter or interfere with the endocrine system. These so-called environmental estrogens can mimic estrogen and have been associated with health and reproductive problems in wildlife and laboratory animals. In humans, the reproductive tract of males begins to develop between the 7th and 14th week of pregnancy. The appearance of additional estrogen and/or progesterone during this phase can trigger the reversal of gender.



INVESTIGATION 16.1 Introduction

Observing Embryo Development

The transformation of a zygote to an embryo to a fetus is a remarkable process. The zygote undergoes many cell divisions, each of which doubles the number of cells. As the number of cells increases, they also begin to differentiate, eventually forming various tissues and organs. It is very difficult to view these events in humans. However, the early stages of all vertebrates are very similar. In this investigation, you can begin to

Report Checklist

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| <input type="radio"/> Purpose | <input type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input checked="" type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input checked="" type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

appreciate what occurs in the development of a human embryo by observing embryo development in frogs.

To perform this investigation, turn to page 545.



Figure 6
Dr. Keith Bagnall

Canadian Achiever—Dr. Keith Bagnall

Dr. Keith Bagnall (**Figure 6**) is a professor in the Division of Anatomy and a member of the Perinatal Research Centre at the University of Alberta. His research interests include the development of the vertebral column, focusing on congenital anomalies, and the development of scoliosis (curvature of the spine) and osteoarthritis.

Dr. Bagnall takes his passion for teaching and learning into high schools and teacher conferences. Among other topics, he explains the crucial steps of fetal development and the negative consequences when an embryo is exposed to chemicals such as nicotine and alcohol. His engaging, interactive presentations have earned him the Distinguished Service Award from the ATA Science Council. Visit the Nelson Web site to learn more about Dr. Bagnall's research contributions.

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DID YOU KNOW?

Teratogenesis

Teratogenesis is a medical term from the Greek, literally meaning 'monster making.'

teratogen any medication, chemical, infectious disease, or environmental agent that might interfere with the normal development of a fetus or embryo

Effects of Environmental Agents on Embryonic Development

The dependency of a newborn on its mother provides a special relationship. However, the dependency prior to birth is even greater. The health and lifestyle decisions of the mother remain with her child for a lifetime.

Proper nutrition prevents many developmental problems. Spina bifida is a relatively common condition that results from a failure of the spinal cord to develop properly. This defect is associated with low levels of folic acid, a member of the B vitamin complex. Because the nervous system is formed in the first month of development (often before a woman knows she is pregnant), some physicians recommend folic acid supplementation for all women of childbearing years.

Lifestyle choices also affect the development of the embryo. Research has demonstrated that women who smoke have smaller babies. This can in part be attributed to the drug nicotine (found in cigarettes) which constricts blood vessels. The reduced blood flow to the placenta means that less oxygen and fewer nutrients are available for growth of the fetus. One study has shown that women who smoke while pregnant have lower levels of vitamin C, even when they consume as much vitamin C as the members of a control group. Smoking may affect the utilization of other nutrients as well.

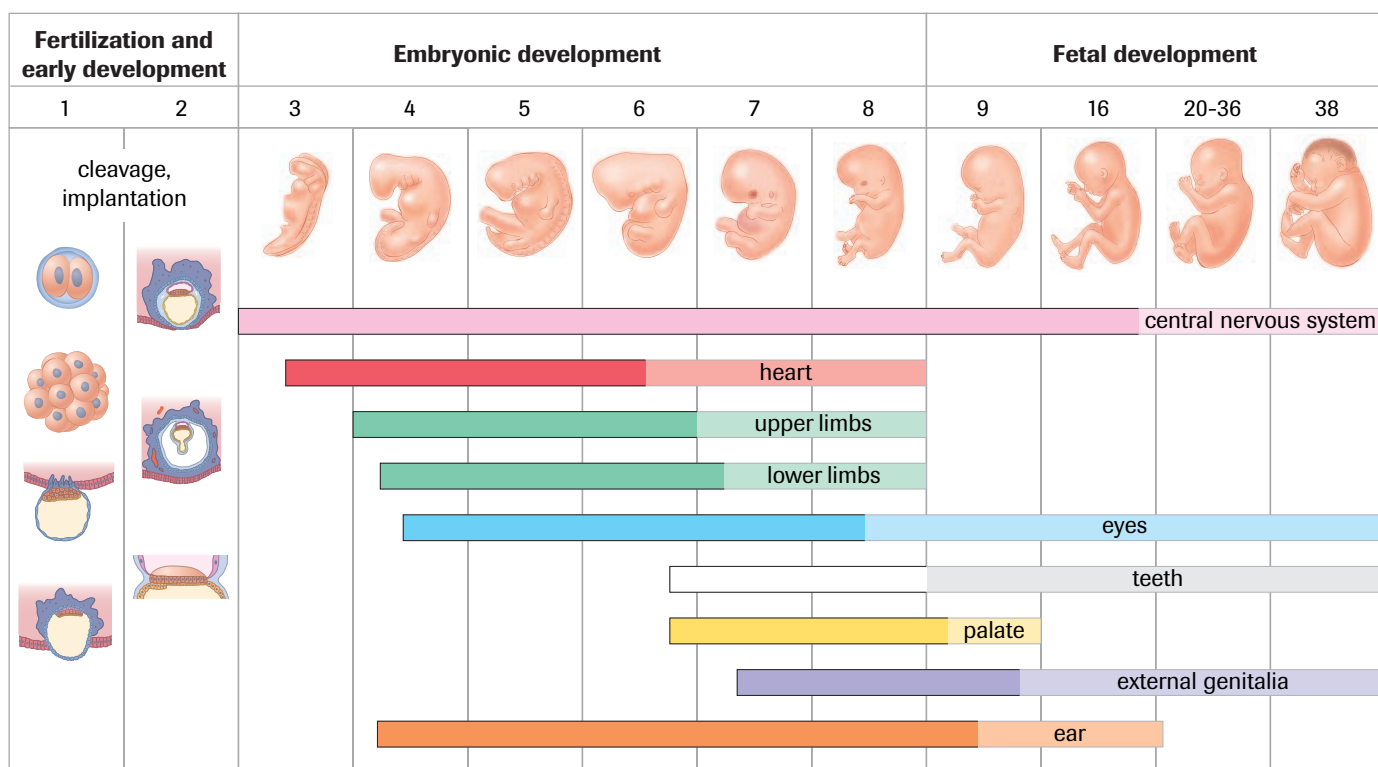
Agents (chemicals and microbes) that are capable of causing developmental abnormalities *in utero* are called **teratogens** (**Table 3**). A number of drugs that can cross the placental membrane have been suspected of adversely affecting fetal development. Most teratogens cause problems early in fetal development. Some organ systems, such as the nervous system, are sensitive to teratogens very early during pregnancy (**Figure 7**, next page).

Practice

2. Outline the events of development during the first, second, and third trimester.
3. Why is an embryo less susceptible to teratogens prior to implantation?

Table 3 Effect of Teratogens on the Developing Embryo

Groups	Agents	Effects on embryo
social drugs	alcohol	Alcohol crosses the placenta to the baby. It can accumulate in the amniotic fluid surrounding the baby before the birth and cause problems such as miscarriage, stillbirth, bleeding during pregnancy, and premature births.
	cigarettes	Carbon monoxide and nicotine reduce the amount of oxygen available in the mother's blood, which can affect the development and size of the baby.
	cocaine	Cocaine increases the heart rate in both the mother and baby, and the supply of oxygen and blood to the baby is reduced, which makes it more likely that the baby will be small and grow slowly. Several cases of bleeding in the brain have been reported in babies whose mothers were dependent on cocaine.
medications	thalidomide	Thalidomide blocks blood vessels that lead to the limbs.
	seizure medication (Dilantin, Tegretol, and valproic acid)	Seizure medication reduces blood flow to the central nervous system.
infectious diseases	rubella	The rubella virus enters the respiratory tract via airborne droplets and spreads to the lymphatic system.
	genital herpes	A pregnant woman who develops genital herpes can pass the virus to her fetus. This produces a higher risk of premature delivery. Newborns rarely become infected with herpes; however, half of those who do become infected either die or suffer neurological damage.

**Figure 7**

Periods of system and organ development during embryonic and fetal development. Dark areas indicate stages of development that are most sensitive to the effects of teratogens.



Fetal Alcohol Spectrum Disorder

The placenta is a selective barrier that prevents the mother's blood cells from entering the circulatory system of the fetus. Smaller molecules, however, can move across the membrane. Unfortunately, some harmful agents, such as alcohol, are small enough to cross the placenta. When a mother takes in alcohol, it crosses the placenta and enters the blood of the fetus (**Figure 8**). As the mother drinks, the fetus absorbs alcohol.

The effects on the fetus are the same as those on the mother: alcohol impairs the functioning of the nervous system and it is a depressant. It is also a poisonous substance. Like other poisons, it is broken down by the liver. Unfortunately, the liver of a fetus is not fully developed until the very final stages of pregnancy, and alcohol cannot be broken down quickly. This means that alcohol remains in its most harmful form much longer in the fetus than it does in the mother. Not only can alcohol kill many of the cells of the fetus, but it has also been linked to changing a cell's genetic information.

Fetal alcohol spectrum disorder (FASD) is a host of birth defects associated with excessive alcohol consumption. Dr. Matthew Hicks, who researches FASD at the University of Calgary, indicates that although FASD is preventable, it is one of the most common birth defects in Canada. FASD crosses all cultural and ethnic boundaries, but occurs only in children born to mothers who consumed alcohol during pregnancy. Children with FASD may have physical abnormalities such as a low body weight, slowed development, deformed organs, a poorly formed rib cage, limited joint movement, and missing digits, as well as distinctive facial features such as a small head, thin upper lip, and small jaw bone. Symptoms of FASD can also include abnormalities of the nervous system, which can cause learning disabilities, poor hand and finger coordination, irritability in infancy, and hyperactivity in childhood.

Approximately 60 % to 70 % of women who are alcoholics give birth to babies with FASD. What may be most disturbing is that evidence suggests that the problem may be getting worse. A 1997 study indicated that four times as many pregnant women admitted to "frequent" drinking in 1995 as compared with a similar 1991 poll. Among 1,313 pregnant

Issue Checklist

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Figure 8

Alcohol passes from the mother's blood across the placenta into the baby.

women, 3.5 % said they drank an average of seven or more drinks a week or had consumed five or more drinks on at least one occasion in the previous month.

Understanding the Issue

1. What is FASD?
2. Why are scientists concerned with decreasing the number of women who drink?
3. What are some symptoms of an FASD baby?

Statement

Pregnant women should be required to have blood tests on a regular basis to monitor drinking problems.

- In your group, discuss the statement and the points and counterpoints in **Table 4**. Write down additional points and counterpoints that your group considered.

Table 4 Perspectives on Requiring Pregnant Women to Have Blood Tests

Point	Counterpoint
FASD is the third most common reason for babies being born with mental retardation in Canada and the United States. Alcohol consumption affects mother and baby. Heart defects and defects of the nervous system are most common.	The idea of suspending the rights of pregnant women is unbelievable. All people would hope that mothers would recognize their responsibility, but legislation is not the answer. Changes in attitudes are accomplished best through education.
Despite a growing awareness that avoiding alcohol prevents the disorder, about one-fifth of pregnant women continue to drink even after they learn they are pregnant.	Most birth defects occur in the period between two weeks and three months of development, when the organs are forming. Does this mean that women should be monitored to ensure that they have a well-balanced diet? Many factors have been linked to birth problems by scientific studies.

- Decide whether your group agrees or disagrees with the statement.
- Conduct research for information on FASD and other preventable birth defects.
- Prepare to defend your group's position in a class discussion.

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WWW WEB Activity

Web Quest—Fetal Rights and FASD

The issue of giving human rights to fetuses is very controversial in Canada and elsewhere. If a fetus were to be given human rights, then pregnant women who behaved in ways that risk the health of a fetus, such as by consuming alcohol, could be held criminally responsible for any damage done as a result. Some people find this unfair to women struggling with addictions. Others think that it is unfair that the children of such women may have to struggle throughout their lives with health problems caused by their mothers' addictions. The Canadian government has so far held off deciding whether to give human rights to fetuses. Its stance is that the issue is too complex and that there should be careful consideration of all the potential consequences before such legislation is proposed.

In this Web Quest, you will gather information on this issue as it relates to Fetal Alcohol Spectrum Disorder (FASD), decide where you stand on the issue, and then prepare to defend your viewpoints in a debate. You will consider whether a father of a FASD child can sue the mother, the legal precedents that have already been set in Canada, and what rights a fetus in Canada currently has.

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Birth

Approximately 266 days after implantation, uterine contractions signal the beginning of **parturition**, or labour. The cervix thins and begins to dilate (**Figure 9 (a)**, next page). As the amnion is forced into the birth canal, it often bursts, and amniotic fluid lubricates the canal (a process referred to as the breaking of the water) (**Figure 9 (b)**, next page). As the cervix dilates, uterine contractions move the baby through the birth canal (**Figure 9 (c)** and **(d)**, next page). Following the birth of the baby, the placenta is also delivered.

Hormones play a vital role in the birthing process. **Relaxin**, a hormone produced by the placenta prior to labour, causes the ligaments within the pelvis to loosen and the cervix to soften, providing a more flexible passageway for the baby during delivery. Although the mechanism is not completely understood, it is believed that a decreased production of progesterone is crucial to the onset of labour. **Oxytocin**, a hormone from the pituitary gland, causes strong uterine contractions. Prostaglandins, which are also believed to trigger strong uterine contractions, appear in the mother's blood prior to labour.

Labour can be induced by administering prostaglandins or pitocin, which is a synthetic form of the hormone oxytocin. The medication stimulates uterine contractions.

CAREER CONNECTION



Midwife

Midwives care for women and infants through pregnancy, labour, delivery, and after a birth. They also provide information about the changes that occur during pregnancy, the development of the fetus, birthing procedures, and newborn growth and development. Would you enjoy educating men and women about pregnancy and birth?

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parturition the act of giving birth; labour

relaxin a hormone produced by the placenta prior to labour; causes the ligaments within the pelvis to loosen

oxytocin a hormone from the pituitary gland; causes strong uterine contractions

+ EXTENSION



Hormones, Labour, and Parturition

Listen to a discussion of the positive feedback cycle that starts the uterine contractions leading to parturition.

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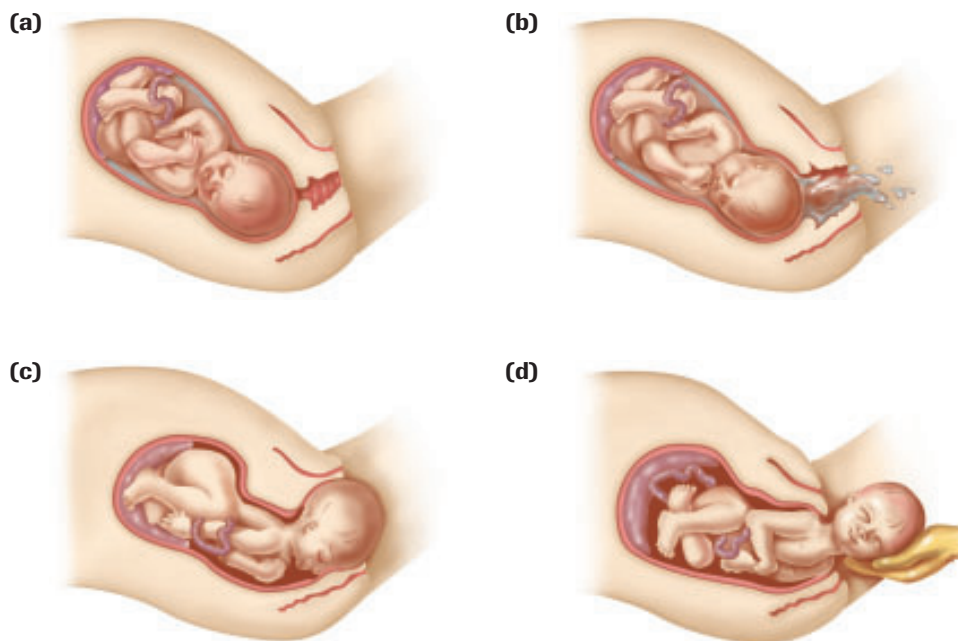


Figure 9

Parturition (labour) begins when **(a)** the cervical opening starts to enlarge. Next **(b)**, the amniotic sac breaks and fluid flows out. Contractions of the uterine muscles push the baby from the uterus **(c)** until it emerges from the birth canal **(d)**.

Lactation

Breast development is stimulated from the onset of puberty by estrogen and progesterone. During pregnancy, elevated levels of estrogen and progesterone prepare the breasts for milk production. Each breast contains about 20 lobes of glandular tissue, each supplied with a tiny duct that carries fluids toward the nipple (**Figure 10**). A hormone called **prolactin**, produced by the pituitary gland, is responsible for stimulating glands within the breast to begin producing fluids. Estrogen stimulates the release of large amounts of prolactin during pregnancy; milk production does not occur before birth, however, because the action of prolactin is inhibited by the high levels of progesterone that are present. The drop in estrogen and progesterone levels after birth results in decreased *amounts* of prolactin, but an increase in prolactin *activity* because the progesterone-induced inhibition is relieved. Prolactin initially causes the production of colostrum, a fluid that closely resembles breast milk. Colostrum contains milk sugar and milk proteins, but lacks the milk fats found in breast milk. A few days after birth, prolactin stimulates the production of milk. Colostrum and mother's milk supply the baby with an important source of antibodies.

Although prolactin increases milk production, the milk does not flow easily. Milk produced in the lobes of glandular tissue must be forced into the ducts that lead to the nipple. The suckling action of the newborn stimulates nerve endings in the areola of the breast. Sensory nerves carry information to the pituitary gland, causing the release of oxytocin. The hormonal reflex is completed as oxytocin is carried by the blood to the breasts and uterus (**Figure 11**). Within the breast, oxytocin causes weak contractions of smooth muscle, forcing milk into the ducts. Within the uterus, oxytocin causes weak contractions of smooth muscle, allowing the uterus to slowly return to its pre-pregnancy size and shape.

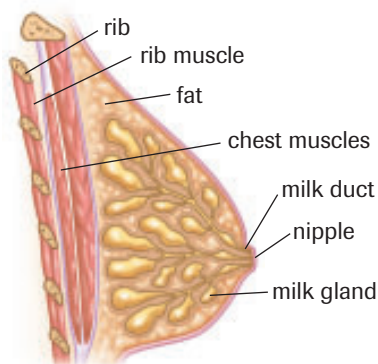
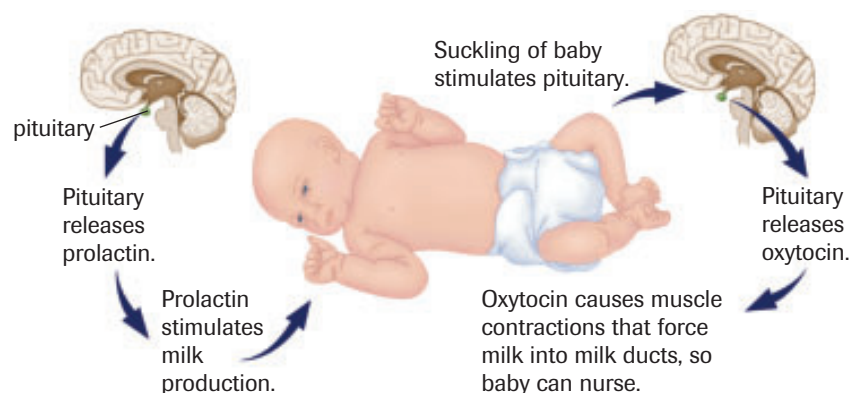


Figure 10

Structure of the human breast

prolactin a hormone produced by the pituitary gland and associated with milk production

**Figure 11**

The hormone prolactin stimulates the breast to produce milk. The suckling action of the baby initiates a hormonal reflex involving the hormone oxytocin.

Although most North American mothers prefer to end breast-feeding once their youngster begins to develop teeth, women in some countries, especially where sources of protein are scarce, often continue to breast-feed for four or five years. Milk production causes a metabolic drain on the mother. At the height of lactation a woman can produce as much as 1.5 L of milk each day. A mother producing that much milk would lose approximately 50 g of fat and up to 100 g of lactose sugar. In addition, a breast-feeding mother would have to replace some 2 to 3 g of calcium phosphate each day. To maintain adequate levels of calcium and phosphate, the parathyroid glands enlarge and bones decalcify. Failure to replace the needed calcium results in a progressive deterioration of the skeleton and teeth.

WEB Activity

Case Study—Creating a Database of Sexually Transmitted Infections

Worldwide, sexually transmitted infections (STIs) find more than 250 million hosts each year. STIs are easily spread through any person-to-person transfer of bodily fluids such as semen, vaginal secretions, or blood. If left untreated, some STIs can cause inflammation and scarring of reproductive passages, leading to infertility. STIs can also result in other serious health problems. The database you will create in this Web Activity will help people find information about STIs.

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CAREER CONNECTION



Pediatrician

Pediatricians specialize in children's health. They assess the well-being of newborns to adolescents, and may diagnose and treat a wide range of problems, such as infections, congenital abnormalities, or cancer. Would you like to be part of a health care professional team working with children?

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+ EXTENSION



The Face of AIDS

AIDS is a sexually transmitted infection that is still spreading. This video explores how this disease is affecting families in regions of Africa where AIDS continues to spread.

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Human Reproductive Technology

Reproductive technology gives individuals, who would not otherwise be able to have a baby, a chance at parenthood. Few technologies have raised interest and concern the way that reproductive technology has. Reproductive technology is changing not only the way in which babies are born, but also the laws that decide parenthood and responsibility.

Fertility Drugs

Fertility drugs stimulate the action of pituitary hormones (Figure 12). Follicle development within the ovary is enhanced and the release of one or more egg cells becomes more probable. Because fertility drugs increase follicle development within the ovary causing multiple ovulations, the chances of having fraternal twins increases.

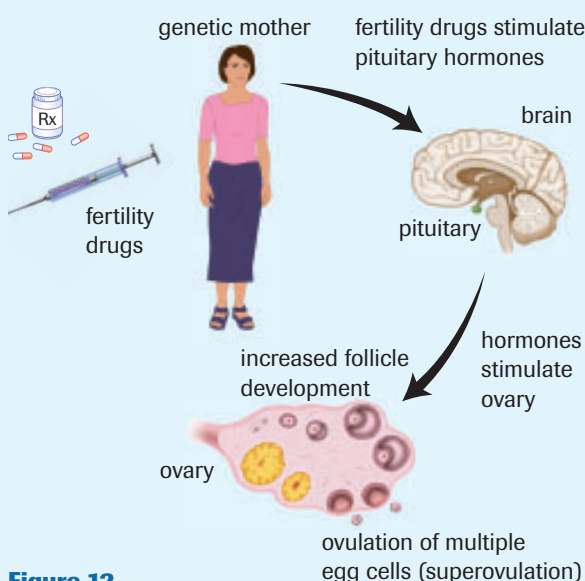


Figure 12
Fertility drugs

Intrauterine Insemination

Sperm cells, either from the woman's partner or from a sperm donor, are transferred into the uterus of the woman following ovulation (Figure 13). Most sperm cells normally die before they reach the egg cell and this technique ensures that greater numbers of motile sperm cells reach the egg.

Cytoplasmic Transfer

The cytoplasm from an egg from a younger woman is transferred into the egg cell of an older woman. It is believed that the cytoplasm from the younger woman's egg will reduce the probability of genetic defects following fertilization.

Gamete Intrafallopian Transfer (GIFT)

Sperm and eggs are inserted in the Fallopian tube. The technique is believed to increase the chances of successful fertilization by bringing sperm and egg cells together.

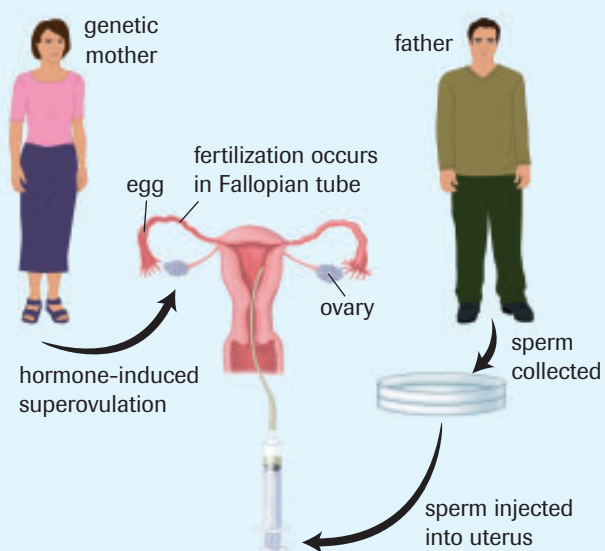


Figure 13
Intrauterine insemination

In Vitro Fertilization

The ovaries are hormonally prepared for ovulation. A device called a laparoscope is inserted into the woman's abdomen (Figure 14). An optical device within the instrument enables the physician to locate the ovary. A suction apparatus within the laparoscope allows the extraction of eggs from the ovary. The eggs are placed in a dish and fertilized by the partner's sperm (in vitro literally means 'in glass'). Following a brief incubation period, one or more of the embryos is transferred into the uterus.

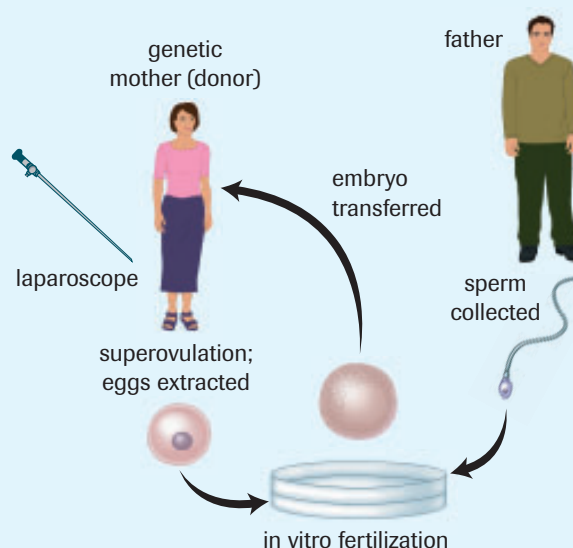


Figure 14
In vitro fertilization

Egg Donations and Egg/Embryo Freezing

Fertility drugs are employed to initiate multiple ovulations. Although a single egg may be fertilized, excess eggs are frozen (**Figure 15**). At a later date, these eggs can be thawed. Some of the eggs could be fertilized and the embryos implanted back into the same mother. Alternatively, unfertilized eggs could be given to another woman who either had no eggs in her ovary or was unable to ovulate.

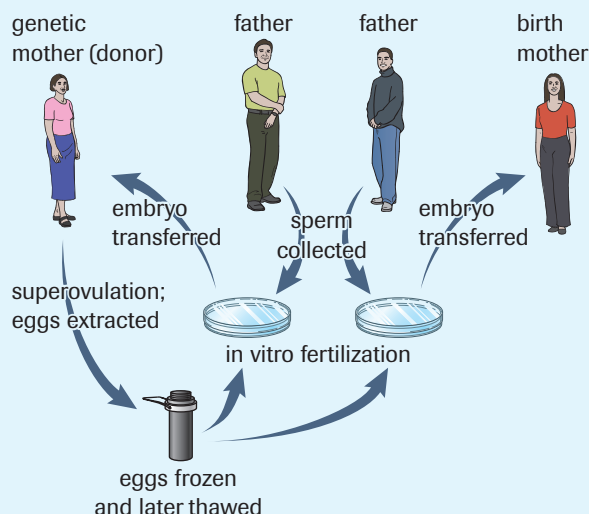


Figure 15

Egg donation and egg/embryo freezing

Embryo Transfer

Combining the technologies of in vitro fertilization and artificial insemination permits another procedure (**Figure 16**). A woman with a defective cervix or uterus may ask another woman (surrogate) to give birth to her genetic child. In this case, the egg from the woman is combined with the sperm of her partner. Fertilization occurs in vitro. The egg is transferred to the surrogate who carries the baby to term and then returns it to the genetic parents. The two technologies raise a fundamental question. Is the mother the one who gives birth or the one who contributes the genetic information?

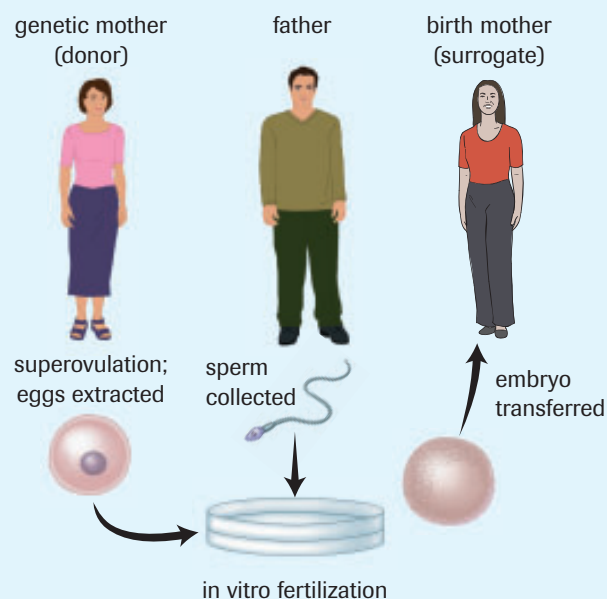


Figure 16

Embryo transfer

Case Study Questions

1. Identify one disadvantage of using fertility drugs.
2. Why might in vitro fertilization be used?
3. If a woman has a cervix that fails to hold the developing fetus in the uterus, then a premature birth can be expected. Despite advancing technology that helps premature babies complete development outside the uterus, the prospects for babies born prior to six months is not good. What reproductive technologies could be employed if a woman wants to be the genetic mother?
4. Explain how a baby could have five different parents if reproductive technology was used.
5. What ethical issues might arise when unused eggs or embryos are donated to parents who cannot produce their own? What should be done with abandoned embryos?



Web Quest—Reproductive Technologies

Reproductive technologies offer hope to couples seeking to have children, but these technologies do not come without a cost. In addition to the financial cost, there are ethical, moral, and legal issues. This Web Quest guides you through the legal, moral, ethical, and general issues surrounding reproductive technologies. To complete the Web Quest, you will carry out research on one reproductive technology and create a multi-media presentation highlighting what you learned.

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+ EXTENSION



Mind-Boggling Births

There is a higher risk of having more than one baby per pregnancy when couples use some reproductive technologies. This video discusses problems this can sometimes cause.

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SUMMARY

Fertilization and Pregnancy

- In humans, fertilization and cleavage takes place in the Fallopian tubes. Cleavage is the division of cells in which the cell number increases but the embryo stays the same size.
- When the embryo reaches the uterus, it attaches to the wall of the endometrium.
- The implanted embryo secretes hCG, which maintains the corpus luteum. The corpus luteum secretes progesterone and estrogen to prevent shedding of the endometrium (menstruation).
- Changes in hormone levels in a pregnant woman's body trigger the formation of structures that protect and nurture the developing embryo changes, including the amniotic cavity, the placenta, and the umbilical cord.
- The implanted embryo develops into a gastrula, which has three layers: ectoderm, mesoderm, and endoderm. Each of these layers forms specific structures in the body.
- Pregnancy is divided into three trimesters. Development of the embryo takes place in the first trimester. Development of the fetus takes place over the last two trimesters.
- Birth begins with parturition (labour). During labour, uterine contractions are triggered by the hormone oxytocin. The hormone relaxin loosens the pelvis and softens the cervix.
- Breast development is stimulated by estrogen and progesterone levels during pregnancy. Milk production is stimulated by prolactin. After birth, suckling triggers release of oxytocin, which stimulates release of milk.
- Reproductive technologies can help people with lower fertility to have children.

► Section 16.3 Questions

1. What is a blastocyst?
2. Explain how hCG maintains pregnancy during the first three months.
3. After about 20 weeks, human development is less sensitive to teratogens. How does this relate to events in embryo and fetal development?
4. Draw a positive feedback response for the release of oxytocin during labour.
5. Chlamydia is an STI caused by infection with a bacterial pathogen. A person can have chlamydia and have no symptoms. In women, untreated infection can spread into Fallopian tubes and cause permanent damage. By referring to events during fertilization and pregnancy, describe why damage to the Fallopian tubes can make a woman unable to bear children.
6. In Alberta, the number of teenage pregnancies has been described as alarming. Two very different solutions have been proposed by groups to address this concern. Visit the Nelson Web site for research information to assist you in answering the following questions:
 - (a) Information on abstinence and support for teens practicing abstinence has been suggested as the best possible solution to the issue. Research why some groups advocate this solution.
 - (b) Other groups propose harm reduction strategies that provide teens with information on contraceptives. Survey different methods of contraception and assess the effectiveness of each methodology.
 - (c) Construct a chart that compares the advantages provided by abstinence and contraception. Which personal values would make one solution preferable to another?

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INVESTIGATION 16.1

Observing Embryo Development

Although vertebrates vary greatly as adults, their initial stages of development are surprisingly similar. The stages of development of a human embryo therefore can be appreciated by observing embryo development in other species.

Purpose

To observe structures of developing frog embryos

Materials

microscope slide
tweezers
prepared slides frog embryology set
light microscope

Procedure and Evidence

- Obtain prepared slides of developing frog embryos and examine them using the low power of the microscope.
- Use **Figures 1, 2, and 3** to identify the different structures. Make labelled diagrams of the slides you view.

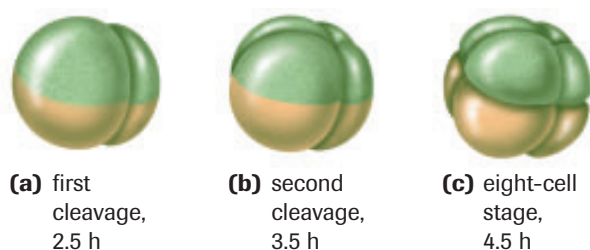


Figure 1

After fertilization, the zygote undergoes a series of divisions that transform it into a tadpole.

- The first cleavage divides the egg into two sections.
- The next cleavage is perpendicular to the first and divides the egg into four sections.
- The next cleavage, dividing the embryo into eight cells, occurs crosswise.

Learning Tip

See Appendix A6 Scientific Drawing for a review of how to make a labelled scientific diagram.

Report Checklist

- | | | |
|--|---|---|
| <input type="radio"/> Purpose | <input type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input checked="" type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

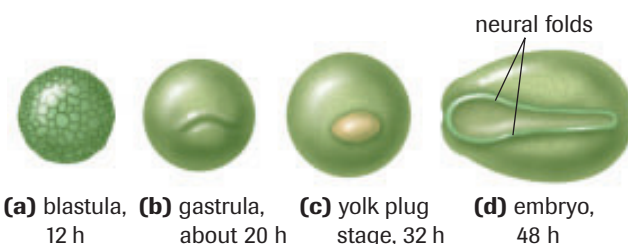


Figure 2

- By the 64-cell stage, the embryo forms a hollow ball called a blastula.
- At the gastrula stage, the embryo has three primary germ layers: ectoderm, mesoderm, and endoderm.
- The yolk plug now protrudes from the inner layer.
- The neural folds develop along what will become the back of the embryo. Cells in this area will develop into the spinal cord and brain.

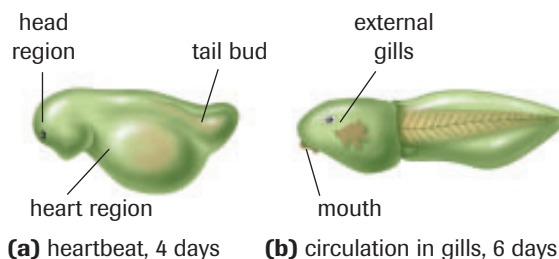


Figure 3

- On day 4, beating of the heart is visible.
- After 6 days, blood can be seen moving through the developing gills.

Analysis and Evaluation

The early stages of vertebrate development have many similarities. Compare the stages of development of frog embryos that you observed and sketched, to the stages of human development shown in **Table 2** on page 534. Organize your response in a table or other appropriate format. Include both similarities and differences.

Outcomes

Knowledge

- identify the structures in the female reproductive system and describe their functions, i.e., ovaries, Fallopian tubes, uterus, cervix, vagina, endometrium, fimbriae, allantois (16.2)
- identify the structures in the male reproductive system and describe their functions, i.e., testes, seminiferous tubules, interstitial cells, Sertoli cells, epididymides, vasa (ductus) deferentia, Cowper's glands, seminal vesicles, prostate gland, ejaculatory duct, urethra, penis (16.1)
- distinguish egg and sperm from their supporting structures, i.e., seminiferous tubules, interstitial cells, Sertoli cells, follicle, corpus luteum (16.1, 16.2)
- describe the chromosomal factors and hormonal influences on the formation of the gonads and reproductive organs in the female and male embryo and fetus, i.e., Y chromosome and role of testosterone (16.3)
- explain how sexually transmitted infections can interfere with fertility and reproduction (16.3)
- describe the role of hormones (gonadotropic-releasing hormone (GnRH), FSH, LH, estrogen, progesterone, testosterone, inhibin) in the regulation of primary and secondary sex characteristics in females and males (16.1, 16.2)
- identify the principal reproductive hormones in the female and explain their interactions in the maintenance of the menstrual cycle, i.e., estrogen, progesterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH) (16.2)
- identify the principal reproductive hormones in the male and explain their interactions in the maintenance and functioning of the male reproductive system, i.e., testosterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH) (16.1)
- trace the processes of fertilization, implantation, and extra-embryonic membrane formation; i.e., amnion, chorion, followed by embryo development, placental and fetal development, parturition and lactation, and the control mechanisms of the above events, i.e., progesterone, LH, human chorionic gonadotropin (hCG), oxytocin, prolactin, prostaglandins (16.3)
- describe development from fertilization to parturition in the context of the main physiological events that occur in the development of organ systems during each major stage (trimester), i.e., zygote, blastocyst, gastrulation, general morphogenesis (16.3)
- identify major tissues and organs that arise from morphological development of the ectoderm, mesoderm, and endoderm, i.e., ectoderm: nervous system, epidermis; mesoderm: skeleton, muscles, reproductive structures; endoderm: lining of the digestive and respiratory systems, endocrine glands (16.3)

- describe the influence of environmental factors on embryonic and fetal development of body structures or systems (16.3)
- describe the physiological or mechanical basis of different reproductive technology methods, i.e., conception control, in vitro fertilization, infertility reversal (16.3)

STS

- explain that decisions regarding the use of scientific and technological developments involve a variety of perspectives, including social, cultural, environmental, ethical, and economic considerations (16.3)
- explain how science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs (16.3)
- explain that science and technology are developed to meet societal needs and expand human capability (16.2, 16.3)

Skills

- ask questions and plan investigations (all)
- conduct investigations and gather and record data and information by: observing the principal features of the human reproductive system using models or computer simulations, and identifying the major structures from drawings (16.1, 16.2); using a microscope to observe prepared slides of ovaries and testes so as to distinguish eggs and sperm from their supporting structures, i.e., follicle, corpus luteum, seminiferous tubules, interstitial cells, Sertoli cells (16.1, 16.2); graphing the changes in estrogen, progesterone, and LH and FSH levels in the blood of a female through a single menstrual cycle (16.2); using models, diagrams, or computer simulations, identifying the follicle and corpus luteum within the ovary (16.2); investigating the effects of environmental factors on embryo and fetal development (16.3)
- analyze data and apply mathematical and conceptual models by: evaluating practical solutions to decreased fertility, i.e., low sperm count, difficulty in egg production, hormonal imbalance (16.3); analyzing blood hormone data and physiological events for a single menstrual cycle, inferring the roles of female sex hormones (16.2); analyzing blood hormone data and physiological events, inferring the roles of male sex hormones (16.1); observing the changes during embryo development, using preserved material such as chicken embryos, prepared slides, models, or computer simulations, and extrapolating these events to the development of a human (16.3); evaluating, from published data, the effectiveness and safety of various reproductive technologies (16.3) and; interpreting hormonal data from published investigations (16.1, 16.2)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms

16.1

testes	epididymis
ovary	acrosome
fertilization	seminal fluid
zygote	seminal vesicle
embryo	prostate gland
fetus	Cowper's (bulbourethral) gland
scrotum	primary sexual characteristics
vas deferens	secondary sexual characteristics
ejaculatory duct	testosterone
semen	interstitial cell
seminiferous tubules	gonadotropic hormones
spermatogenesis	follicle-stimulating hormone (FSH)
spermatogonia	luteinizing hormone (LH)
spermatocyte	gonadotropin-releasing hormone (GnRH)
spermatid	inhibin
somatic cell	
Sertoli cell	

16.2

ovum	corpus luteum
oocyte	menstruation (flow phase)
uterus (womb)	follicular phase
endometrium	estrogen
Fallopian tube (oviduct)	ovulatory phase
fibrium (plural: fibria)	luteal phase
vagina	progesterone
cervix	menopause
oogenesis	follicle-stimulating hormone (FSH)
follicle	luteinizing hormone (LH)
granulosa	
ovulation	

16.3

cleavage	chorionic villi
blastocyst	allantois
implantation	umbilical cord
chorion	first trimester
amnion	gastrulation
human chorionic gonadotropic hormone (hCG)	gastrula
amniotic cavity	ectoderm
extraembryonic coelom	mesoderm
yolk sac	endoderm
placenta	second trimester
	third trimester

teratogen

parturition

relaxin

oxytocin

prolactin

▶ MAKE a summary

1. Hormones control many events in the reproductive system. Create a table, spreadsheet, or use presentation software to list the hormones involved in each of the following events and summarize their roles:
 - spermatogenesis
 - the menstrual cycle
 - birth
 - lactation
2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

▶ Go To

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The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 16
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

▶ UNIT 30 B PERFORMANCE TASK

Society and Reproductive Technology

In this Performance Task, you will use the knowledge and skills you gained in this Unit to survey how much knowledge the public has, prepare an information display, and/or write a futuristic play related to reproductive technology. Go to the Unit 30 B Performance Task link on the Nelson web site to complete the task.

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Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

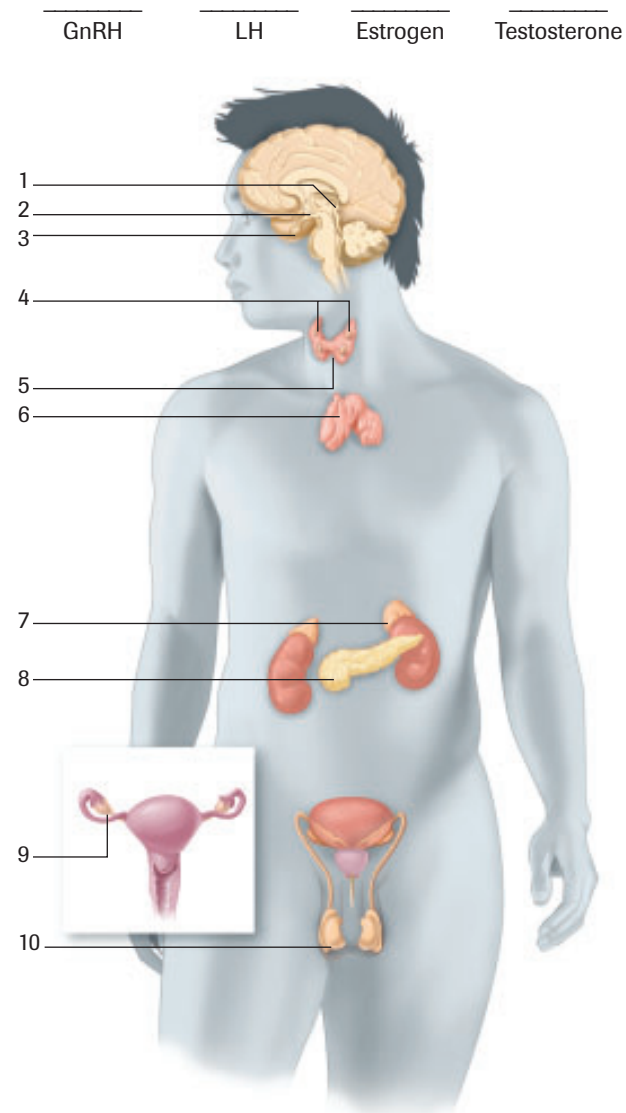
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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

- 1.** Using the numbers from **Figure 1**, identify the site of production for each of the listed hormones. (Record all four digits of your answer).



- 2.** Which statement identifies a homeostatic response for LH and testosterone?
- If testosterone levels increase, then LH production decreases. If LH levels increase, then testosterone production decreases
 - If testosterone levels increase, then LH production increases. If LH levels increase, then testosterone production increases
 - If testosterone levels increase, then LH production decreases. If LH levels increase, then testosterone production increases
 - If testosterone levels increase, then LH production increases. If LH levels increase, then testosterone production remains constant
- 3.** The hormonal mechanism that regulates sperm production is
- LH production increases and sperm production decreases
 - LH production decreases and sperm production increases
 - FSH production increases and sperm production increases
 - FSH production increases and sperm production decreases
- 4.** Which of the following are a function of testosterone in males? (Record all three digits of your answer in lowest-to-highest order.)
- stimulates spermatogenesis
 - stimulates the production of sperm cells in the seminiferous tubules
 - stimulates secretion of FSH and LH
 - promotes and regulates the development of secondary sexual characteristics
 - associated with sex drive levels
- 5.** Menstruation begins when
- there are no longer any eggs remaining in the ovary
 - estrogen levels rise and progesterone levels begin to decline
 - FSH and LH secretions decrease and the corpus luteum deteriorates
 - progesterone levels increase and positive feedback to the pituitary increases the LH secretions
- 6.** In females, LH is a gonadotropin that
- promotes the development of the follicle in the ovary
 - inhibits the development of the endometrium in the uterus
 - promotes ovulation and formation of the corpus luteum in the ovary
 - inhibits the release of progesterone from the follicle cells in the ovary

Figure 1

7. In the female reproductive system, the roles of estrogen and progesterone, respectively, are to
- initiate ovulation and promote the growth of the endometrium
 - initiate ovulation and stimulate the development of the follicles in the ovary
 - stimulate the development of secondary female characteristics and the development of the corpus luteum
 - stimulate the development of secondary female characteristics and promote the growth of the endometrium
8. The function of the female menstrual cycle is to
- produce mature ova and provide a nutrient-rich environment for a zygote
 - prevent invading microbes from taking up residence in the uterus and to ensure ovulation
 - create an environment suitable for the survival of sperm cells and enable fertilization
 - maintain constant levels of estrogen and progesterone, which help develop a mature endometrium
9. In humans, the stage of development in which the major organs begin to differentiate is the
- zygote
 - fetus
 - embryo
 - blastocyst
10. Place the following in the order in which they occur during embryo and fetal development. (Record all four digits of your answer.)
- Cleavage occurs.
 - The ectoderm, mesoderm, and endoderm are formed.
 - The blastula is formed.
 - Gastrulation occurs.
11. The extraembryonic structure responsible for secreting hCG is the
- amnion
 - chorion
 - allantois
 - placenta

Use the following information to answer questions 12 and 13.

Figure 2 shows structures in a pregnant woman that support the developing embryo at 4 weeks.

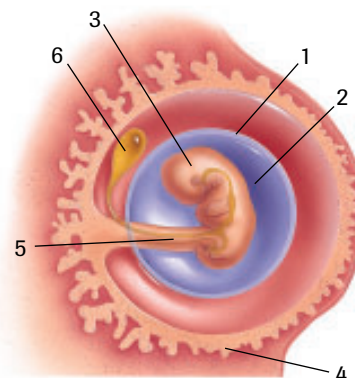


Figure 2

12. Identify the correct number that identifies structures shown in **Figure 2**. (Record all four digits of your answer.)

_____ embryo _____ umbilical cord _____ amnion _____ chorion

13. Identify the statement that correctly matches the number of the label on Figure 2, the name of the structure, and its function.
- Structure 6 is the yolk sac, which is for early red blood cell formation.
 - Structure 2 is the amnionic cavity, which is for diffusion of nutrients from mother.
 - Structure 5 is the allantois, which is the site of estrogen and progesterone production.
 - Structure 1 is the placenta, which is the site of nutrient and waste exchange between mother and embryo.

14. The following statements describe steps that occur during in vitro fertilization. Reorder them in the sequence in which these steps would be performed. (Record all four digits of your answer.)

- Eggs are extracted.
- Eggs are fertilized by sperm.
- Embryo is transferred to the uterus.
- Embryos are incubated to about the four-cell stage.

Part 2

15. **Predict** the consequences if the testes fail to descend from the abdominal cavity during embryo development.
16. Using **Figure 3**, **explain** how testosterone levels are maintained at constant levels.

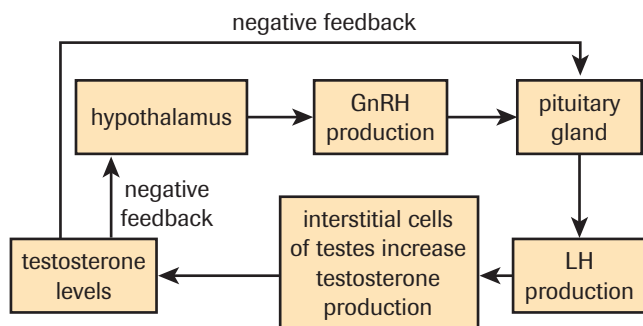


Figure 3

Use the following information to answer questions 17 and 18.

Anabolic steroids have improved the performance levels of athletes. They stimulate certain tissues (muscles in particular) to develop. They are either synthetic or natural versions of testosterone.

17. **Explain** why anabolic steroids often cause lower sperm count?

18. **Why** do anabolic steroids commonly lower levels of testosterone?

19. Some research has shown that males go through hormonal changes, called andropause, similar to menopause. In small groups, conduct research on this topic. Divide your group into two teams and assign teams to either support or refute the existence of male andropause. Can the group as a whole come to an agreement? In an appropriate way of your choosing, **outline** your group's stance and the information you collected that supports it.

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20. **Sketch** a diagram of the female reproductive system. Label the sites of ovulation, fertilization, and implantation.
21. Contraceptive pills contain synthetic estrogen and progesterone.
- How** do contraceptive pills prevent pregnancy?
 - Why** aren't contraceptive pills taken for the entire 28-day menstrual cycle?

Use the following information to answer questions 22 and 23.

Figure 4 shows estrogen and progesterone levels during a menstrual cycle.

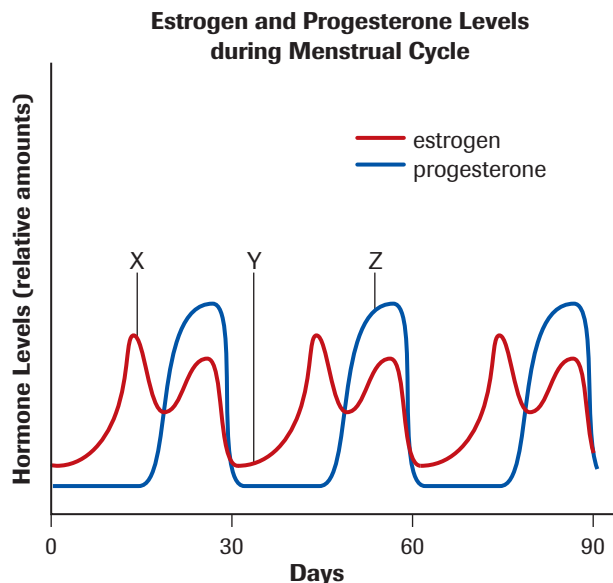


Figure 4

22. **Identify** the day (X, Y, or Z) on which ovulation would occur. **Explain** your answer.

23. **Identify** the day (X, Y, or Z) on which you expect to find a functioning corpus luteum. **Explain** your answer.

24. **Design** an experiment to show how female gonadotropic hormones are regulated by ovarian hormones.

25. **Compare** the functions of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) in both males and females by completing **Table 1**.

Table 1 Functions of FSH and LH in Males and Females

Hormone	Male	Females
follicle-stimulating hormone (FSH)		
luteinizing hormone (LH)		

26. Using changes in hormonal levels, write a unified response to **explain** the following observations as a woman approaches menopause:

- thin endometrium
- no ovulation
- low levels of LH

27. During pregnancy, menstruation is inhibited. **Explain** the hormonal mechanism that maintains the endometrium.
28. **Figure 5** shows hormone levels during the 40 weeks of pregnancy. **Explain** the changes in hCG, estrogen, and progesterone levels during pregnancy.

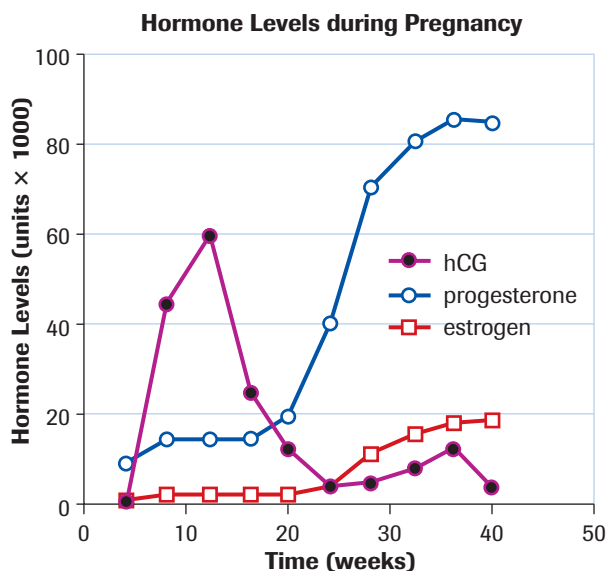


Figure 5

29. Imagine a situation in which a woman's ovaries are removed during the eighth month of pregnancy. **How** will removal of the ovaries affect the fetus? **Explain** your answer.
30. **Describe** the effects of biological parents taking drugs and alcohol on the conception and development of their fetus.
31. Sometimes labour must be induced in order to avoid complications.
 (a) **Identify** a hormone that could be used to aid and induce labour.
 (b) **Explain** why this hormone would be used.
32. How many corpus lutei would be found in the ovaries of a woman who has just given birth to identical twins? Would this number be different if the twins were fraternal? **Explain** why.
33. A couple is unable to have a baby. A number of different factors can reduce the reproductive potential of the male. In a unified response, **explain** why each of the factors could reduce reproductive success.
- blocked vas deferens
 - reduced levels of testosterone
 - testes fail to descend into the scrotum

Use the information in **Figure 6** to answer questions 34 to 36.

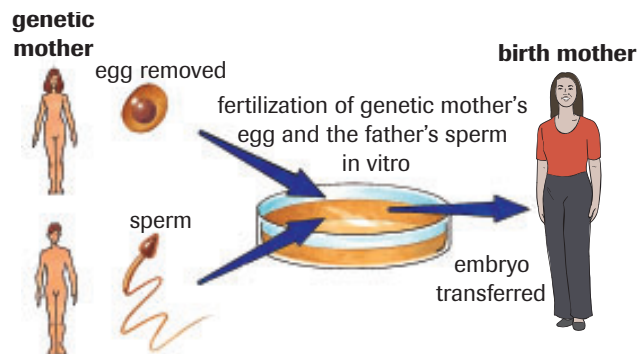


Figure 6

34. **Identify** the reproductive technology shown in **Figure 6**.
 DE
35. **Describe** the reproductive problem that this technology would be used to solve.
 DE
36. **Describe** any legal or ethical issues that might arise from this technology.
 DE
37. Do all human have the right to reproduce? Should someone lose the right to reproduce because they have a history of alcohol or drug abuse? Write a unified response to these two questions that includes the following considerations:
- Who determines if an individual should not be allowed to reproduce?
 - What special circumstances would cause the "right to reproduce" to be questioned?
 - **Why** are legislators reluctant to enter into these discussions?
38. Review the focusing questions on page 506. Using the knowledge you have gained from this unit, briefly outline a response to each of these questions.